PR 29-83 PART II
COMPILATION OF TRADE STUDIES, ENGINEERING ANALYSES AND OTHER REPORTS PREPARED DURING AAP MISSION 1A 60-DAY STUDY

Contract NAS 8-21004

20 September 1967

N68-24580

MARTIN MARIETTA CORPORATION
DENVER DIVISION

FOREWORD

This document, in three parts, consists of trade studies, engineering analyses, and other technical reports prepared during the AAP Early Applications Mission 1A 60-day study period. These reports are support data to the Final Report, PR 29-81.

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TRADE STUDY REPORT

METEOROID VULNERABILITY ANALYSIS OF THE MISSION 1A CARRIER PRESSURE SHELL AND RADIATORS

AAP/PIP EARLY APPLICATIONS

Contract NAS 8-21004

1 September 1967

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MARTIN MARIETTA CORPORATION
DENVER DIVISION

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1.0 INTRODUCTION

1.1 Purpose - The meteoroids of space have long been recognized as a potential hazard to satellites and manned spacecraft. In the case of the Mission 1A Carrier, penetration of the pressure shell and the resultant loss of atmosphere would abort the flight. Likewise, penetration of the heat rejection radiators and the consequent loss of coolant would end the mission. The purpose of this study, then, was to determine the vulnerability of both the pressure shell and radiator to meteoroids and recommend changes if necessary.

1.2 Objectives - The objectives were as follows:

a. Analyze the present design of the Mission 1A Carrier pressure shell.

b. Analyze the present design of the heat rejection radiators.

c. Recommend changes in design as necessary to meet required probabilities of no puncture.

2.0 SUMMARY

A model of the meteoroid environment as published in Reference 1 and Summer's penetration equation as presented in Reference 2 were used to analyze the meteoroid vulnerability of the Mission 1A Carrier pressure shell and radiators. The calculations show:

a. Need for additional protection for the pressure shell.

b. More than adequate protection has been provided for the radiators.

With the addition of a 16 mil thick aluminum bumper between the two subsystem racks and an increase in the dome thickness of 10 mils, the desired probability of no puncture to the pressure shell can be achieved.

3.0 PRESSURE SHELL ANALYSIS

The vulnerability of an orbiting system to the meteoroid environment depends on a combination of factors--the vehicle configuration, the mission altitude and duration, the properties of the meteoroid environment, and the method by which resistance to penetration is calculated.

3.1 Configuration - In evaluating the vulnerability of of the Mission 1A Carrier, it was assumed that the basic configuration was firmly established. No variation of the principal dimensions was therefore considered.

The carrier is a frustum, capped at one end with a dome and at the other end with a docking collar. Attached to the pressure shell are two covered (0.032 inch aluminum) subsystem racks which shield half of the surface area of the frustum. The entire structure is made of aluminum--docking collar is 200 mils thick while the rest of the pressure shell is .040 inch aluminum. Dimensions of the vehicle are shown in Figure 1.

3.2 Mission Parameters - The mission considered was 14 days in duration starting at 140 nautical miles, and decaying to 132, with the dome of the carrier always pointing at nadir. At these altitudes the vehicle will be shielded from 36.2% of the environment by the earth.

3.3 Model Of The Environment And Penetration Equation - The Manned Spacecraft Criteria and Standards Board, NASA-MSC, has published a model of the meteoroid environment which reflects resent measurements by meteoroid satellites of the meteoroid flux in the near-earth cislunar region. This model of the environment, Reference 1, was used to make the calculations of the number of impacts to be expected during the mission. Stream meteoroids were considered by increasing the sporadic flux by a factor of 1.4, as suggested in the reference.

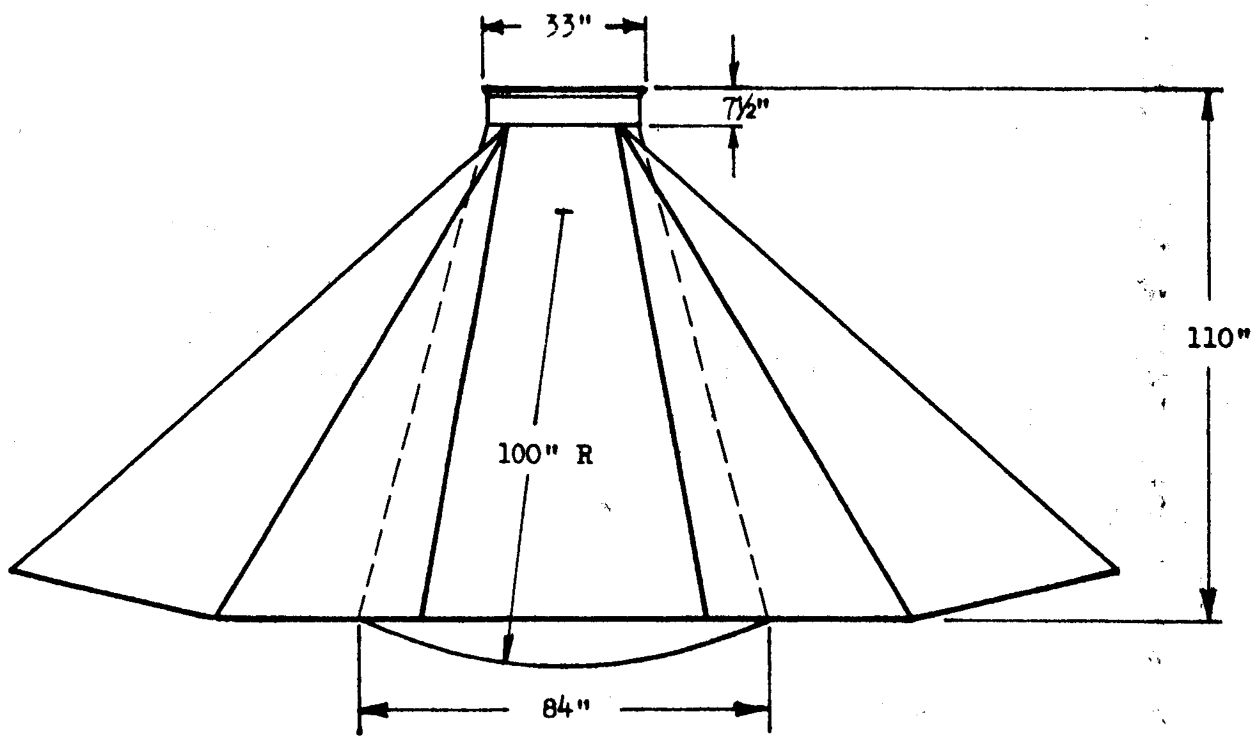

FIGURE 1

ORIGINAL MISSION 1A CARRIER

Summer's penetration equation as presented in Reference 2, including the effectiveness factors for double wall structures, was used in determining probabilities of no puncture.

3.4 Results Of Vulnerability Analysis - The Mission 1A Carrier configuration and mission description presented in Sections 3.1 and 3.2, and the environment and penetration models described in Section 3.3, have been combined to analyze the vulnerability of the carrier to the meteoroid environment. The results are shown in Table 1.

Surface area of the frustum under the subsystem racks was designated as Surface 2; area not under the racks, Surface 1. Some conservatism has been introduced into the calculations by the way this double wall area, Surface 2, has been handled. Because of the limitations of the penetration equation and the complexity of this area (e.g., subsystem equipment dispersed between the walls) it was assumed that Surface 2 was only protected by a 16 mil thick aluminum bumper spaced two inches from the inner .040 inch wall. This is the same protection afforded Surface 1 in the recommended design.

Threshold mass refers to the mass of a meteoroid just able to penetrate the element in question. Threshold hole diameter is the diameter of the hole made by a meteoroid with threshold mass.

In addition to earth shielding, mentioned in Section 3.2, the shielding furnished by the command service module was accounted for in these calculations.

Table 2 shows the results of an analysis of an alternate design in which a 16 mil thick aluminum bumper is placed over Surface 1, spaced two inches out. Dome thickness is increased by 10 mils to .050 inches.

TABLE 1

SUMMARY OF METEOROID VULNERABILITY OF ORIGINAL CARRIER DESIGN

ELEMENT	PUNCTURE RATE*	THRESHOLD MASS**	THRESHOLD HOLE DIAMETER***	PROBABILITY OF NO PUNCTURE	
				INDIVIDUAL	ACCUMULATED
DOCKING COLLAR	3.74×10^{-7}	7.53×10^{-4}	2.67×10^{-1}	.99998	.99998
SURFACE 1	4.68×10^{-5}	6.03×10^{-6}	5.33×10^{-2}	.98499	.98497
SURFACE 2	3.36×10^{-7}	8.40×10^{-4}	2.77×10^{-1}	.99989	.98487
DOME	4.68×10^{-5}	6.03×10^{-6}	5.33×10^{-2}	.99303	.97800

TOTAL AREA LOST TO PUNCTURES = 1.18×10^{-6} SQUARE FEET

* Holes Per Foot Squared Per Day

** Grams

*** Inches

TABLE 2

SUMMARY OF METEOROID VULNERABILITY OF RECOMMENDED CARRIER DESIGN

ELEMENT	PUNCTURE RATE*	THRESHOLD MASS**	THRESHOLD HOLE DIAMETER***	PROBABILITY OF NO PUNCTURE	
				INDIVIDUAL	ACCUMULATED
DOCKING COLLAR	3.74×10^{-7}	7.53×10^{-4}	2.67×10^{-1}	.99998	.99998
SURFACE 1	3.36×10^{-7}	8.40×10^{-4}	2.77×10^{-1}	.99989	.99988
SURFACE 2	3.36×10^{-7}	8.40×10^{-4}	2.77×10^{-1}	.99989	.99977
DOME	2.40×10^{-4}	1.18×10^{-5}	6.67×10^{-2}	.99642	.99619

TOTAL AREA LOST TO PUNCTURES = 5.51×10^{-7} SQUARE FEET

* Holes Per Foot Squared Per Day

** Grams

*** Inches

4.0 RADIATOR ANALYSIS

The environment and penetration models described in Section 3.3 were again used in analyzing the heat rejection radiators of the Mission 1A Carrier. Mission parameters are as described in Section 3.2.

4.1 Configuration - Figure 2 shows a cross-section of the radiators. There are to be four radiator panels, two on each subsystem rack, with connecting tubes running under the proposed meteoroid bumper between the racks. The system is made up of 24 feet of radiators and 72 feet of connecting tubing. For additional meteoroid protection, the system is completely redundant.

4.2 Results Of Vulnerability Analysis - To account for large variations in the thickness and spacing an incoming meteoroid would see, a sector analysis was made of the radiators. Figure 2 also shows the four regions each tube of the radiator was subdivided into. The results of the calculations are displayed in Table 3.

5.0 CONCLUSIONS AND RECOMMENDATIONS

As was shown in Table 1, the desired probability of no puncture of .995 cannot be achieved with the original design of the pressure shell. Surface 1 and the dome being the two most vulnerable elements. The alternate design provides additional protection for these two elements. Most important, this design does meet the desired probability of no puncture. It is, therefore, recommended that the Mission 1A Carrier dome thickness be increased to 50 mils of aluminum and a 16 mil aluminum bumper spaced two inches out be placed over the pressure shell between the subsystem racks.

Table 3 shows that more protection has been provided than is needed for the radiator, and in fact, the redundant system is not necessary for meteoroid protection. If the radiator is redesigned to eliminate the second system, it is recommended that a thicker walled tubing be used in connection with a thinner fin (e.g., .060 inch wall tubing spaced at least one inch below a 20 mil thick aluminum fin).

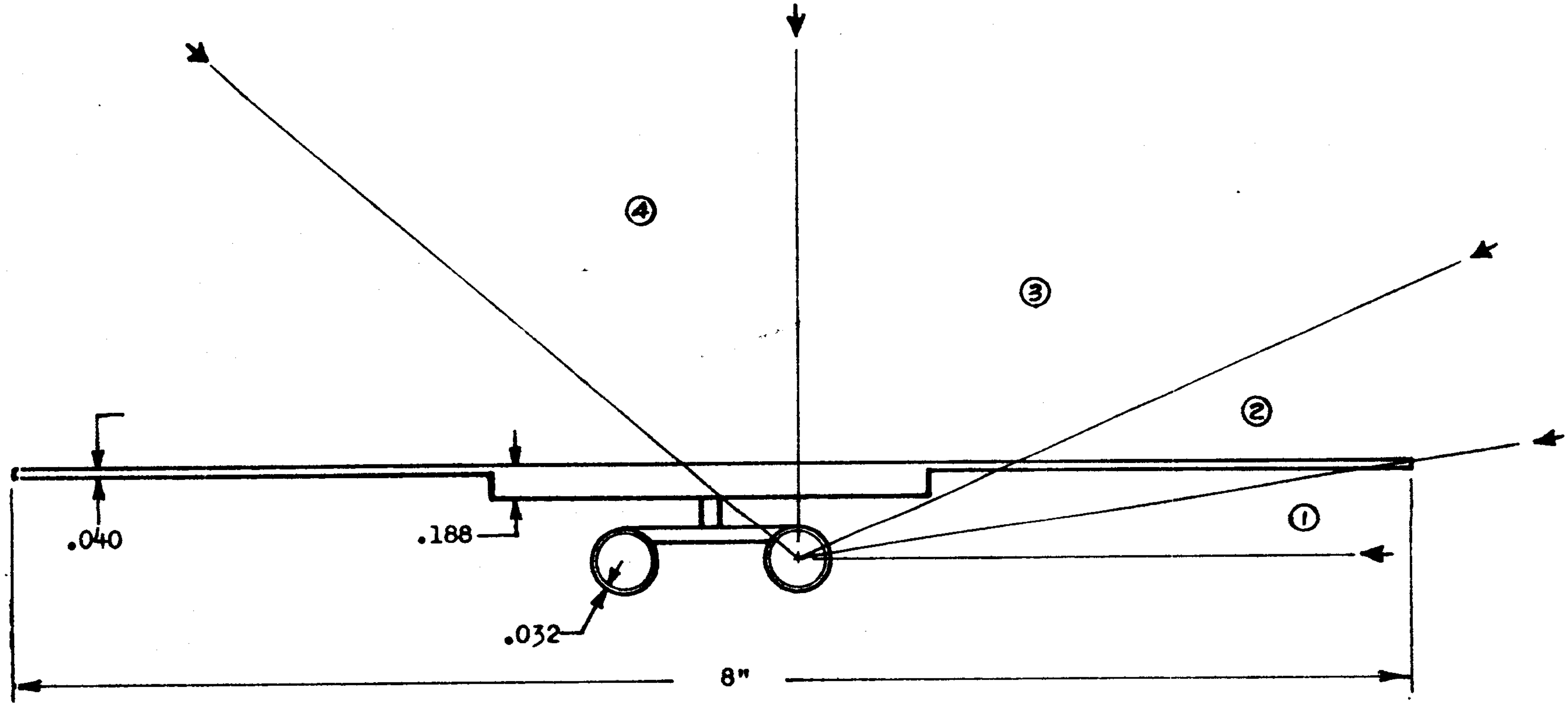

FIGURE 2

CROSS-SECTION OF HEAT REJECTION RADIATOR

MARTIN MARIETTA CORPORATION
DENVER DIVISION

TABLE 3

SUMMARY OF METEOROID VULNERABILITY OF HEAT REJECTION RADIATORS

ELEMENT	PUNCTURE RATE*	THRESHOLD MASS**	PROBABILITY OF NO PUNCTURE			
			INDIVIDUAL		ACCUMULATED	
			ONE SYSTEM	BOTH SYSTEMS	ONE SYSTEM	BOTH SYSTEMS
RADIATOR						
REGION 1	9.14×10^{-5}	3.08×10^{-6}	1.000000	1.000000	1.000000	1.000000
REGION 2	1.10×10^{-6}	2.57×10^{-4}	1.000000	1.000000	1.000000	1.000000
REGION 3	2.06×10^{-5}	1.37×10^{-5}	.999980	.999960	.999980	.999960
REGION 4	5.66×10^{-6}	4.98×10^{-5}	.999997	.999994	.999977	.999954
CROSSOVER TUBES	4.57×10^{-7}	4.85×10^{-4}	.999995	.999990	.999972	.999944

PROBABILITY OF NO PUNCTURES TO THE REDUNDANT SYSTEM = .999944

PROBABILITY OF ONE PUNCTURE OR LESS TO THE SINGLE SYSTEM = 1.000000

PROBABILITY OF ONE PUNCTURE OR LESS TO THE REDUNDANT SYSTEM = .999972

* Holes Per Foot Squared Per Day

** Grams

REFERENCES

1. Design Standards Bulletin 21, Revision A, Meteoroid Environment - Near-Earth And Cis-Lunar. Manned Spacecraft Criteria and Standards Board, NASA. Manned Spacecraft Center, Houston, Texas, 24 January 1967.

2. TOR-269(4560-40)-2, Aerospace Meteoroid Environment And Penetration Equation, V. C. Frost, Aerospace Corporation, El Segundo, California, 17 August 1964.

PR 29-24

TRADE STUDY REPORT

PRELIMINARY COLD PLATE THERMAL STUDY

AAP/PIP EARLY APPLICATIONS

Contract NAS8-21004

29 August 1967

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1. INTRODUCTION

1.1 Purpose - The purpose of this report is to document the results of a preliminary design study for serpentine tube cold plates.

1.2 Objective - The objective of this study was to determine preliminary design and performance criteria for serpentine cold plates. Once structural, manufacturing and thermal requirements are more firmly defined, the chosen cold plate design and performance can be established.

2. SUMMARY

A parametric study of serpentine tubes brazed to the back of a plate was performed to establish the design influences of tube spacing, plate thickness and coolant flow rate. The study was performed by using a simple analytical model of a typical cold plate configuration which was then programed for the IBM 1130 computer.

As expected, the closer the tubes, the thicker the plate and the higher the flow rate, the more efficient the cold plate. The problem of closer tubes is more tube length per plate area increasing weight and pressure drop. It can be concluded from this study, that simple serpentine tube cold plates are suitable for handling the expected heat loads at reasonable pressure losses.

3. DISCUSSION

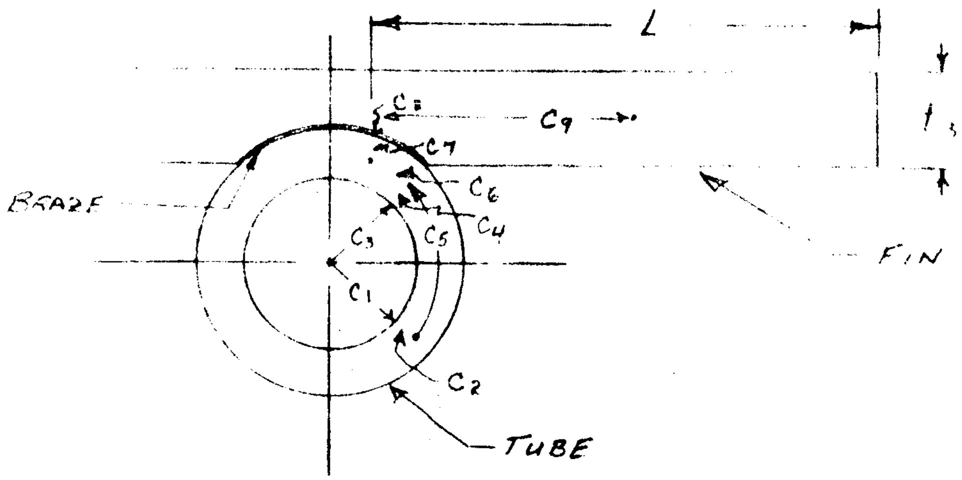
The active coolant loop requires heat exchangers or cold plates to absorb surplus heat for later rejection by the space radiator. The plate-fin type of cold plate design can obtain very high heat transfer efficiencies. Because of the special nature of this type of cold plate, they require design, development and test time which is incompatible with changing requirements.

In order to accommodate schedule requirements and to be flexible to changing configurations and heat load requirements, a cold plate design using a flat plate with a serpentine tube brazed to the back surface is being considered. These cold plates would be designed and built by Martin Marietta Corporation.

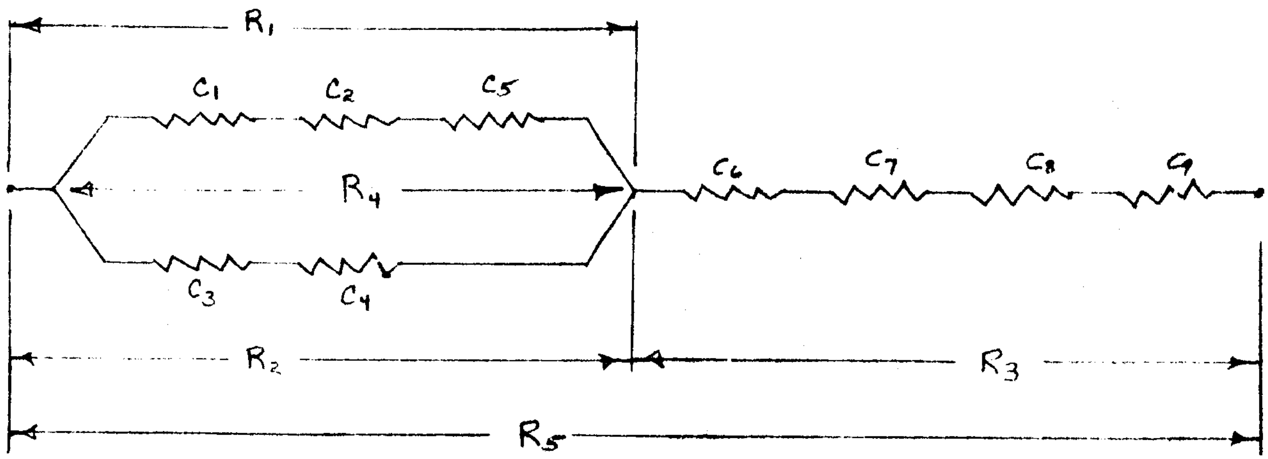
3.1 Serpentine Cold Plate Equations - The cold plate was evaluated based on the configuration shown in Figure 1. This figure shows the basic configuration studied and the electrical, thermal equivalent, network.

FIGURE I - COLD PLATE CONFIGURATION & ELECTRICAL NETWORK

COLD PLATE CONFIGURATION



ELECTRICAL NETWORK



3.1.1 Conductances (per unit tube length)

C_1 = Conductance (coolant to 1/4 tube wall area)

$$C_1 = \frac{h \pi D}{4} \quad (\text{BTU/hr }^{\circ}\text{F})$$

where: h = heat transfer coefficient

$$= \frac{k}{D} (.023) (R_E)^{.8} (P_R)^{.4}$$

k = Coolant thermal conductivity (BTU/hr ft $^{\circ}$F)

D = Tube diameter (ft)

R_E = Reynolds number

P_R = Prandtl number

C_2 = Conductance (1/4 tube wall area to center of tube thickness)

$$C_2 = \frac{k_1 \pi D}{2t}$$

where: k_1 = thermal conductivity of tube (BTU/hr ft $^{\circ}$F)

t = tube thickness (ft)

C_3 = Conductance (coolant to 1/4 tube wall area)

$$C_3 = C_1$$

C_4 = Conductance (1/4 tube wall area to center of tube thickness)

$$C_4 = C_2$$

C_5 = Conductance (through tube wall)

$$C_5 = \frac{4k_1 t}{\pi D}$$

C_6 = Conductance (through tube wall)

$$C_6 = \frac{8k_1 t}{\pi D}$$

C_7 = Conductance (1/8 wall area to braze)

$$C_7 = \frac{k_1 \pi D}{4\ t}$$

C_8 = Conductance (through braze)

$$C_8 = \frac{k_2 \pi D}{t_2}$$

where: k_2 = thermal conductivity of braze (BTU/hr ft °F)

t_2 = braze thickness (ft)

$$C_9 = \frac{2k_3t_3}{L}$$

where: k_3 = thermal conductivity of fin (BTU/hr ft °F)

t_3 = fin thickness (ft)

L = fin length (ft)

3.1.2 Thermal resistances - From the thermal conductances, the overall thermal resistances can be defined.

$$R_1 = \frac{1}{U_1} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_5}$$

$$R_2 = \frac{1}{U_2} = \frac{1}{C_3} + \frac{1}{C_4}$$

$$R_3 = \frac{1}{U_3} = \frac{1}{C_6} + \frac{1}{C_7} + \frac{1}{C_8} + \frac{1}{C_9}$$

$$R_4 = R_4 + R_3 = \frac{R_1\ R_2}{R_2+R_1} + R_3$$

3.1.3 Heat load equations -

$$Q = \frac{1}{R_5} \quad \text{(BTU/hr °F) (Unit tube length)}$$

QAT = Q/Area (BTU/hr ft^2 °F)

AREA = (L) (Unit length) (ft^2) fin area

$Y = \frac{QAT}{WT}$ BTU/16-Ft^2 ^oF

WT = UNIT weight per unit length (tube, coolant, fin)

From the above, Y should be maximized and still meet the requirements of QAT.

3.2 Cold Plate Analysis - The following parameters were considered in the above equations which were programed for the IBM 1130 computer.

Coolant - Freon 21

Coolant flow rate - 600, 400, 200, and 100 lb/hr

Coolant temperature = 60^o F

Tube ID - .311 inches

Tube wall thickness - .03 inches

Braze thickness - .005 inches

Thermal conductivity of tube and fin - 90 BTU/hr ft ^oF

Thermal conducitivity of braze material - 50 BTU/hr ft ^oF

Fin thicknesses - .031, .0625, .125, and .1875 inches

Fin length - .25, .5, .75, 1.0, 1.5, 2.0, 2.5, 3.0 inches

Table I is a summary of some of the influencing parameters found during analysis.

TABLE I

ANALYTICAL INFLUENCING PARAMETERS

Flow Rate, lb/hr	600.	400.	200.	100.
Pressure Drop, lb/in^2 (100 ft length)	11.1	5.5	1.63	.48
Reynolds Number	34116.	22744.	11372.	5686.
h, BTU/hr ft^2 °F	396.	286.	164.	94.
$C_1 = C_3$, BTU/hr °F	8.1	5.8	3.35	1.92
$C_2 = C_4$, BTU/hr °F	1256.2	1256.2	1256.2	1256.2
C_5, BTU/hr °F	12.9	12.9	12.9	12.9
C_6, BTU/hr °F	25.8	25.8	25.8	25.8
C_7, BTU/hr °F	628.1	628.1	628.1	628.1
C_8, BTU/hr °F	1221.3	1221.3	1221.3	1221.3
R_1, Hr °F/BTU	.202	.249	.377	.598
R_2, Hr °F/BTU	.124	.172	.299	.520

Figures 2, 3, 4, and 5 show the heat transfer capability of the cold plates for mounting plate thicknesses of .031, .0625, .125, and .1875 inches, respectively. Each figure shows the influence of tube spacing on the plate and coolant flow rate. It is easily seen that for the greater heat transfer performance, the tubes must be as close together as possible. Also at the lower flow rates, mounting plate thickness is thermally unimportant. These curves show that the heat transfer from the coolant to tube and tube to plate are the controlling terms for heat transfer.

Figures 6, 7, and 8 show that based on weight and for a given flow rate, that the tubes should be as close together as possible and the mounting plate thin for maximum heat transfer for minimum weight. These three figures should be used as a guide in selecting the design since other items (heat rejection requirements, structural requirements and mounting areas) need to be considered. If maximum performance/minimum weight cold plates are required, then a plate-fin type of cold plate should be used.

Figure 9 shows plots of pressure drop versus flow rate and inside tube diameter. With flow rates less than 400 lb/hr being considered, it is seen that pressure drop for a 3/8 inch tube should not be a problem.

4. CONCLUSIONS AND RECOMMENDATIONS

Cold plate designs based on brazing an aluminum tube to the back of an aluminum plate in a serpentine manner are entirely feasible. The actual size and design must be based on requirements of the cooled components. Using the thermal requirements, Figures 2, 3, 4, and 5 can be used to evaluate preliminary designs. Once the preliminary design approach is established, a rigorous thermal analysis is required taking into account all the physical features of construction to finalize the design.

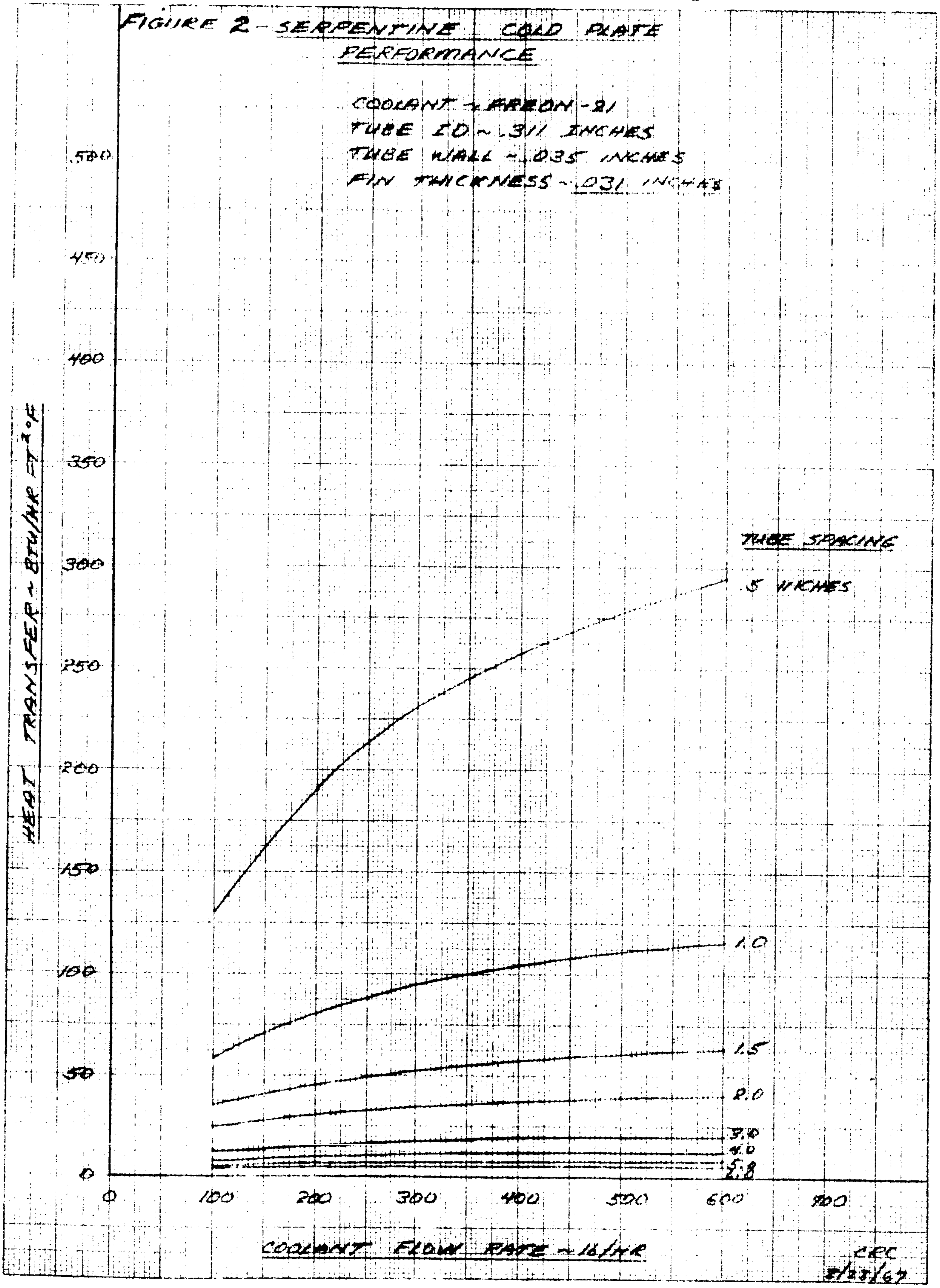


FIGURE 2 - SERPENTINE COLD PLATE PERFORMANCE
COOLANT ~ FREON - 21
TUBE ID ~ .311 INCHES
TUBE WALL ~ .035 INCHES
FIN THICKNESS ~ .031 INCHES
HEAT TRANSFER ~ BTU/HR FT² °F
COOLANT FLOW RATE ~ lb/HR
TUBE SPACING
.5 INCHES
1.0
1.5
2.0
3.0
4.0
5.0
0
50
100
150
200
250
300
350
400
450
500
600
700
CRC
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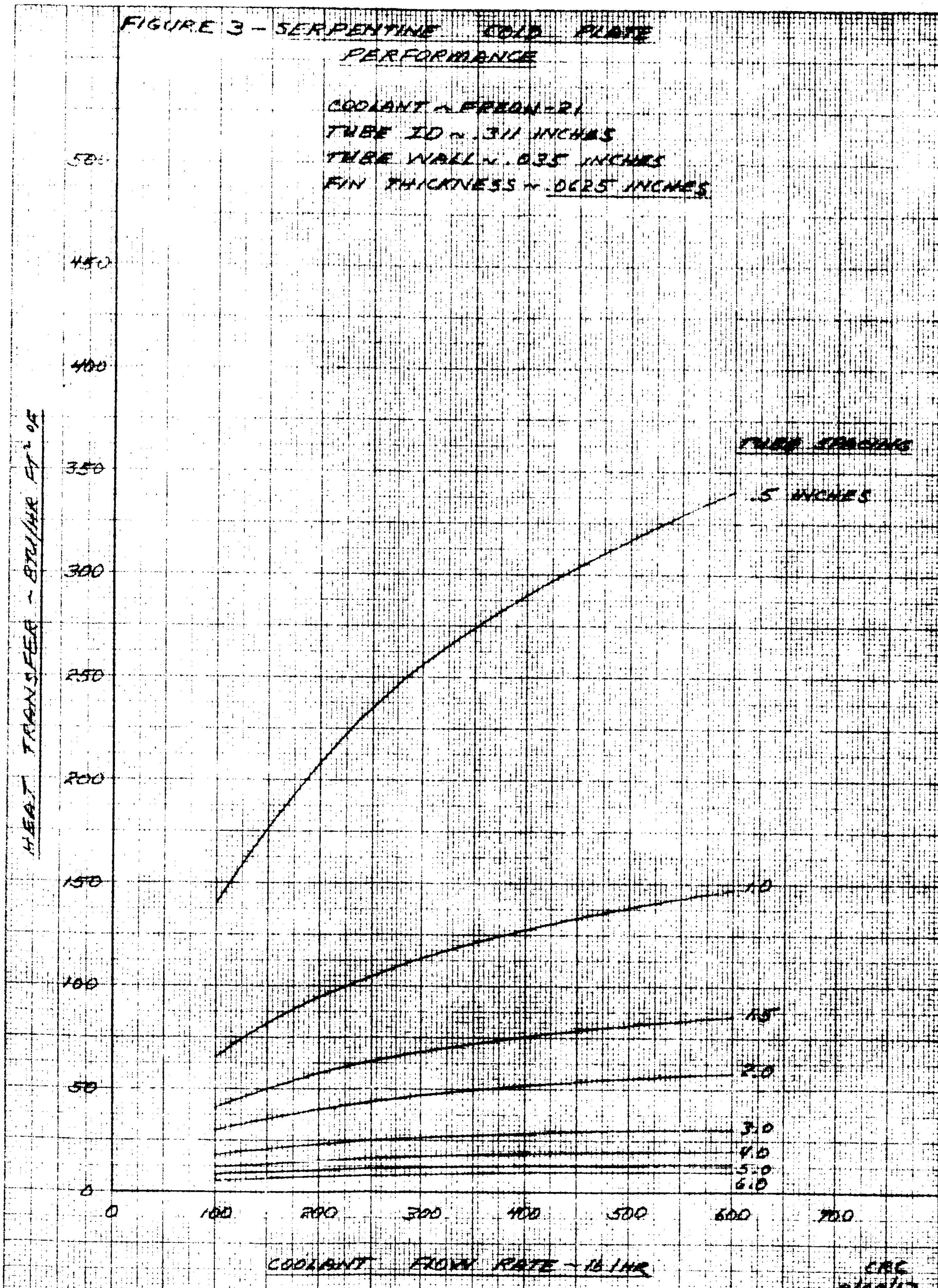
FIGURE 3 - SERPENTINE COLD PLATE PERFORMANCE
COOLANT ~ FREON-21
TUBE ID ~ .311 INCHES
TUBE WALL ~ .035 INCHES
FIN THICKNESS ~ .0625 INCHES
TUBE SPACING
.5 INCHES
1.0
1.5
2.0
3.0
4.0
5.0
6.0
HEAT TRANSFER ~ BTU/HR FT² °F
COOLANT FLOW RATE ~ lb/HR
0
100
200
300
400
500
600
700
50
100
150
200
250
300
350
400
450
500
ERC
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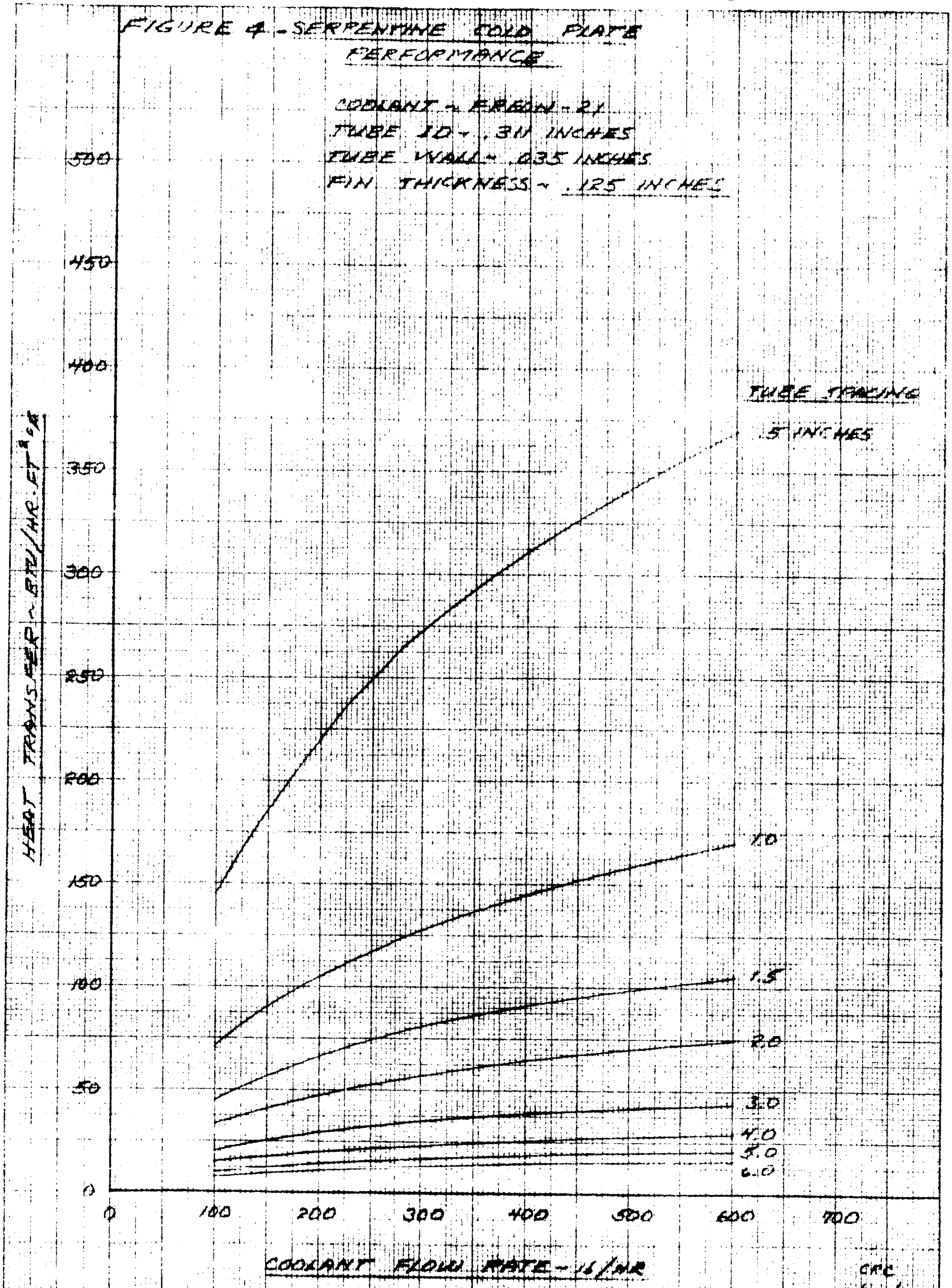
FIGURE 4 - SERPENTINE COLD PLATE PERFORMANCE
COOLANT ~ FREON - 21
TUBE ID ~ .311 INCHES
TUBE WALL ~ .035 INCHES
FIN THICKNESS ~ .125 INCHES
TUBE SPACING
.5 INCHES
1.0
1.5
2.0
3.0
4.0
5.0
6.0
HEAT TRANSFER ~ BTU/HR. FT² °F
COOLANT FLOW RATE ~ lb/HR
0
50
100
150
200
250
300
350
400
450
500
600
700
CPC

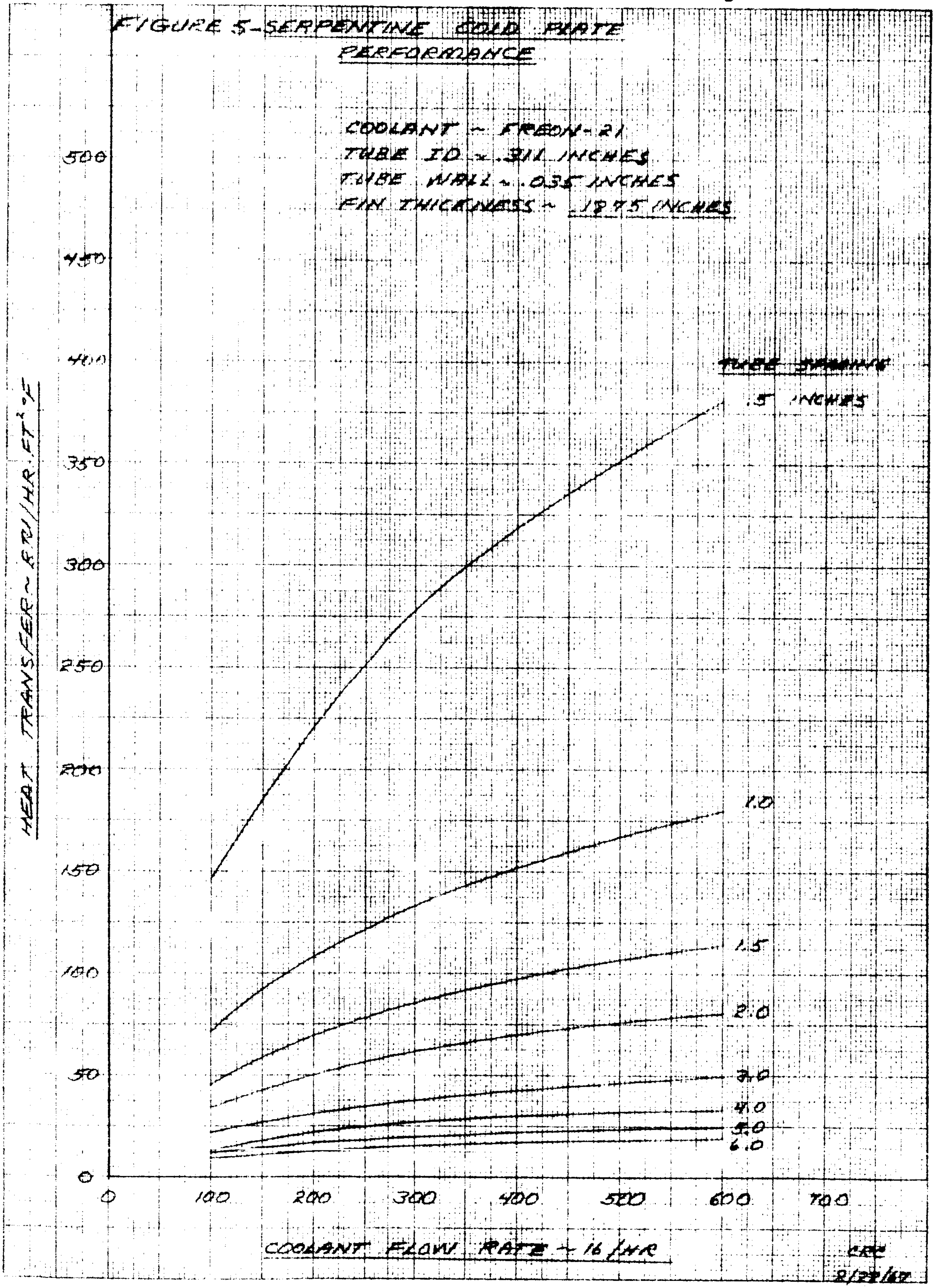
FIGURE 5-SERPENTINE COLD PLATE PERFORMANCE
COOLANT ~ FREON-21
TUBE ID ~ .311 INCHES
TUBE WALL ~ .035 INCHES
FIN THICKNESS ~ .1875 INCHES
TUBE SPACING
.5 INCHES
1.0
1.5
2.0
3.0
4.0
5.0
6.0
HEAT TRANSFER ~ BTU/HR.FT^2°F
500
450
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
COOLANT FLOW RATE ~ lb/HR

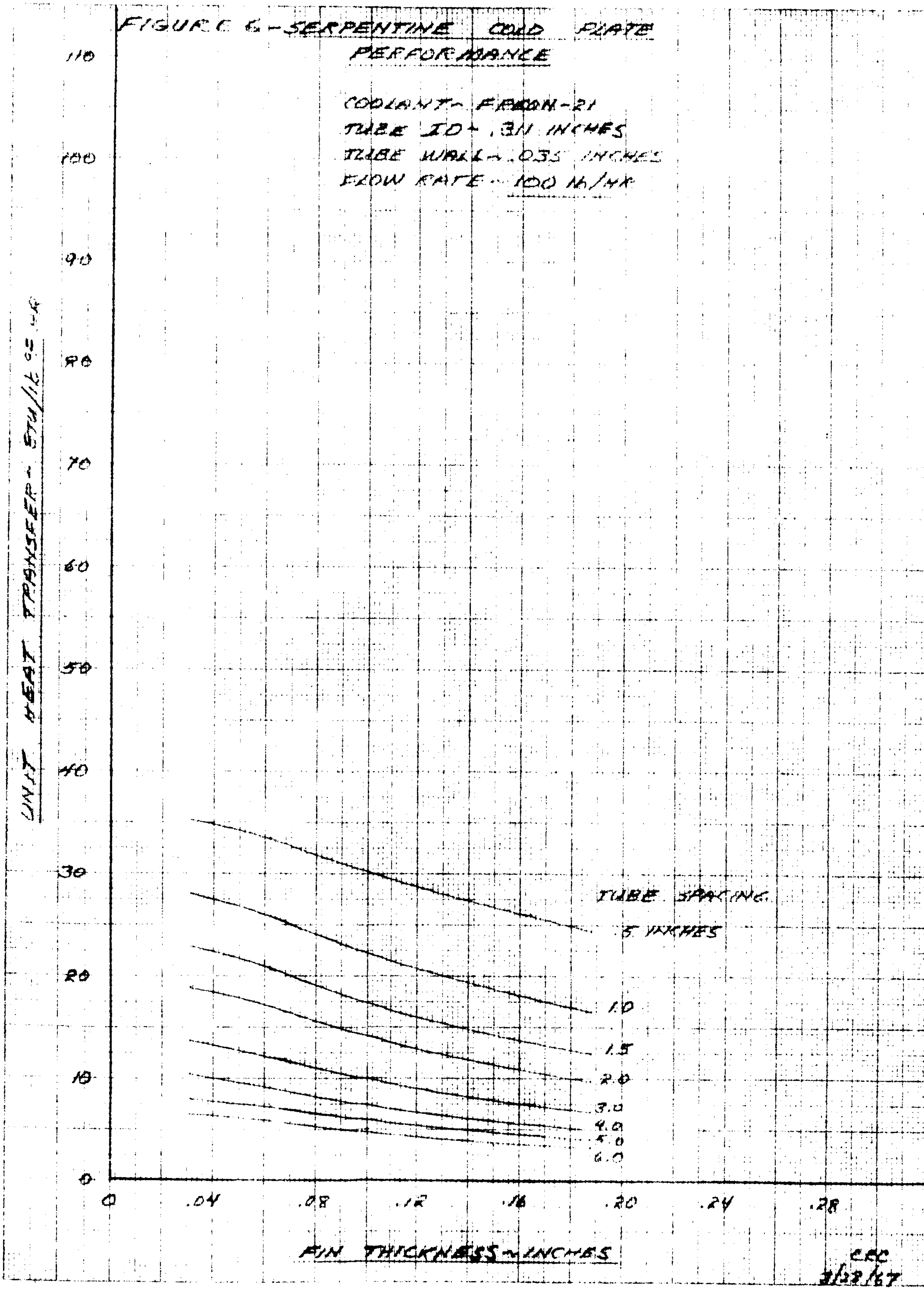
FIGURE 6 - SERPENTINE COLD PLATE PERFORMANCE
COOLANT ~ FREON-21
TUBE ID ~ .311 INCHES
TUBE WALL ~ .035 INCHES
FLOW RATE ~ 100 lb/HR
UNIT HEAT TRANSFER ~ BTU/ft² °F HR
110
100
90
80
70
60
50
40
30
20
10
0
TUBE SPACING
.5 INCHES
1.0
1.5
2.0
3.0
4.0
5.0
6.0
0
.04
.08
.12
.16
.20
.24
.28
FIN THICKNESS ~ INCHES
CEC
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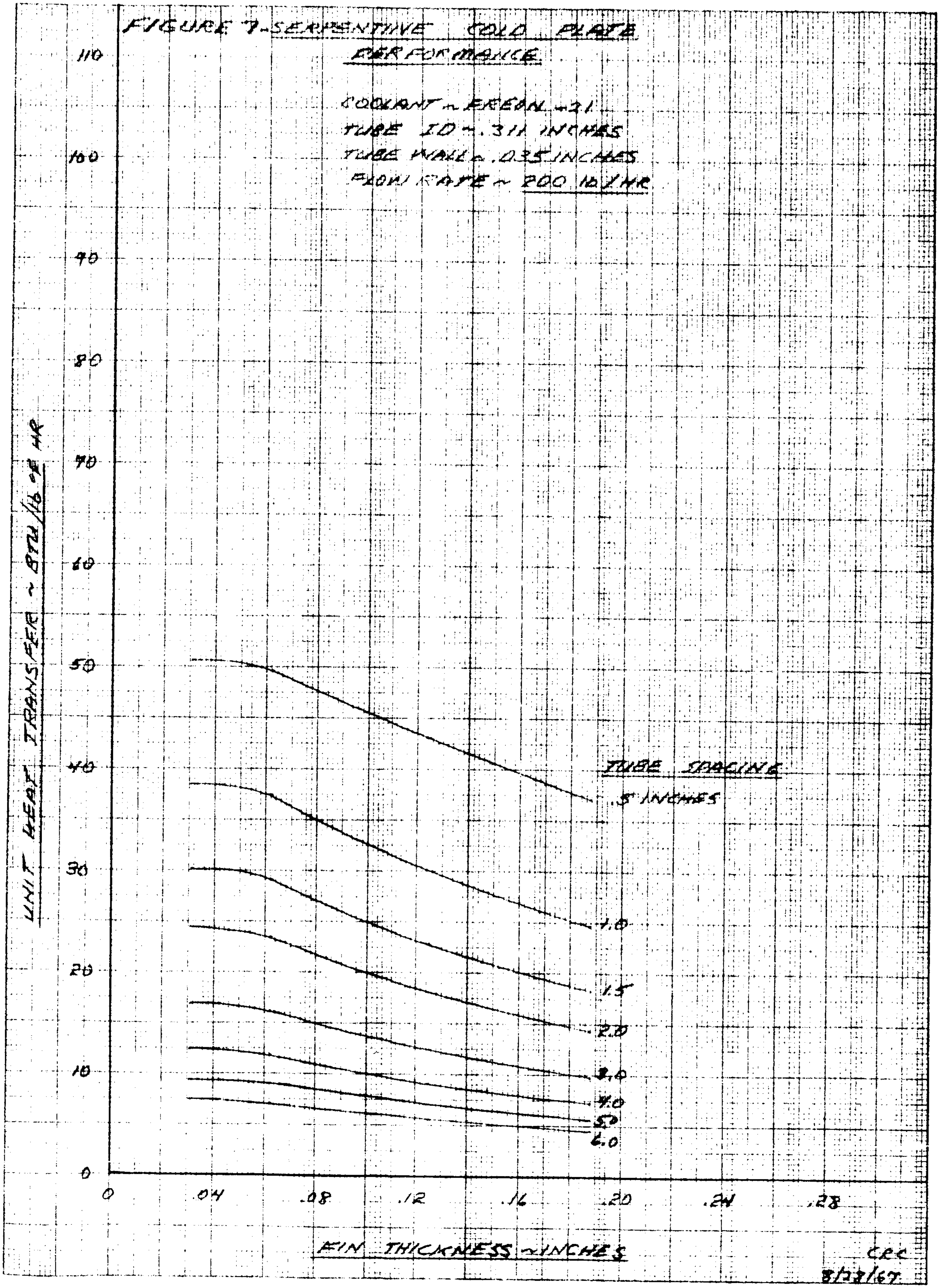
FIGURE 7-SERPENTINE COLD PLATE PERFORMANCE
COOLANT ~ FREON -21
TUBE ID ~ .311 INCHES
TUBE WALL ~ .035 INCHES
FLOW RATE ~ 200 lb/HR
UNIT HEAT TRANSFER ~ BTU/lb °F HR
110
100
90
80
70
60
50
40
30
20
10
0
TUBE SPACING
.5 INCHES
1.0
1.5
2.0
3.0
4.0
5.0
6.0
0
.04
.08
.12
.16
.20
.24
.28
FIN THICKNESS ~ INCHES
CRC
8/23/67

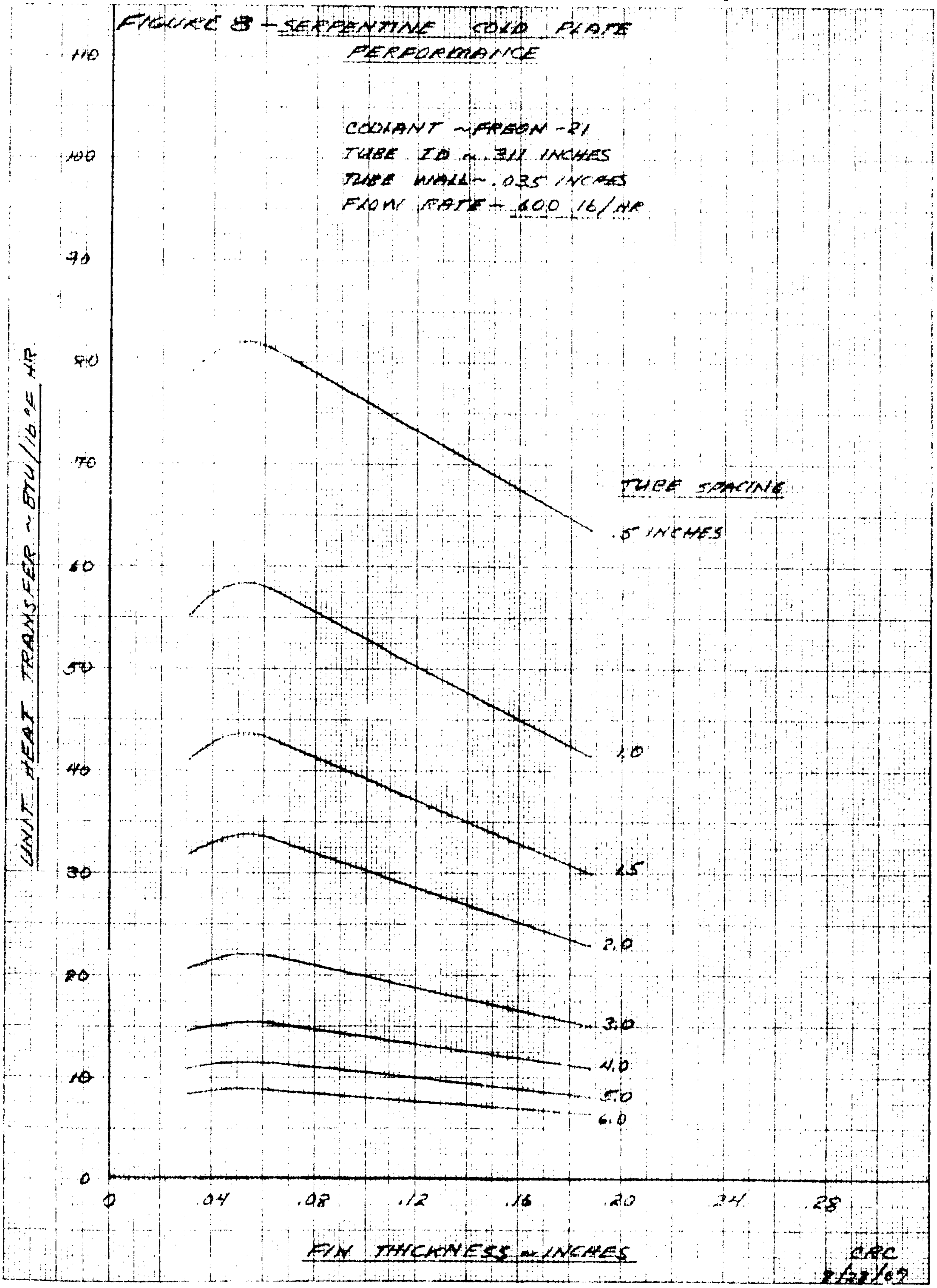
FIGURE 3 - SERPENTINE COLD PLATE PERFORMANCE
COOLANT ~ FREON -21
TUBE ID ~ .311 INCHES
TUBE WALL ~ .035 INCHES
FLOW RATE ~ 600 lb/HR
TUBE SPACING
.5 INCHES
1.0
1.5
2.0
3.0
4.0
5.0
6.0
UNIT HEAT TRANSFER ~ BTU/lb °F HR
110
100
90
80
70
60
50
40
30
20
10
0
0
.04
.08
.12
.16
.20
.24
.28
FIN THICKNESS ~ INCHES
CRC
2/23/67

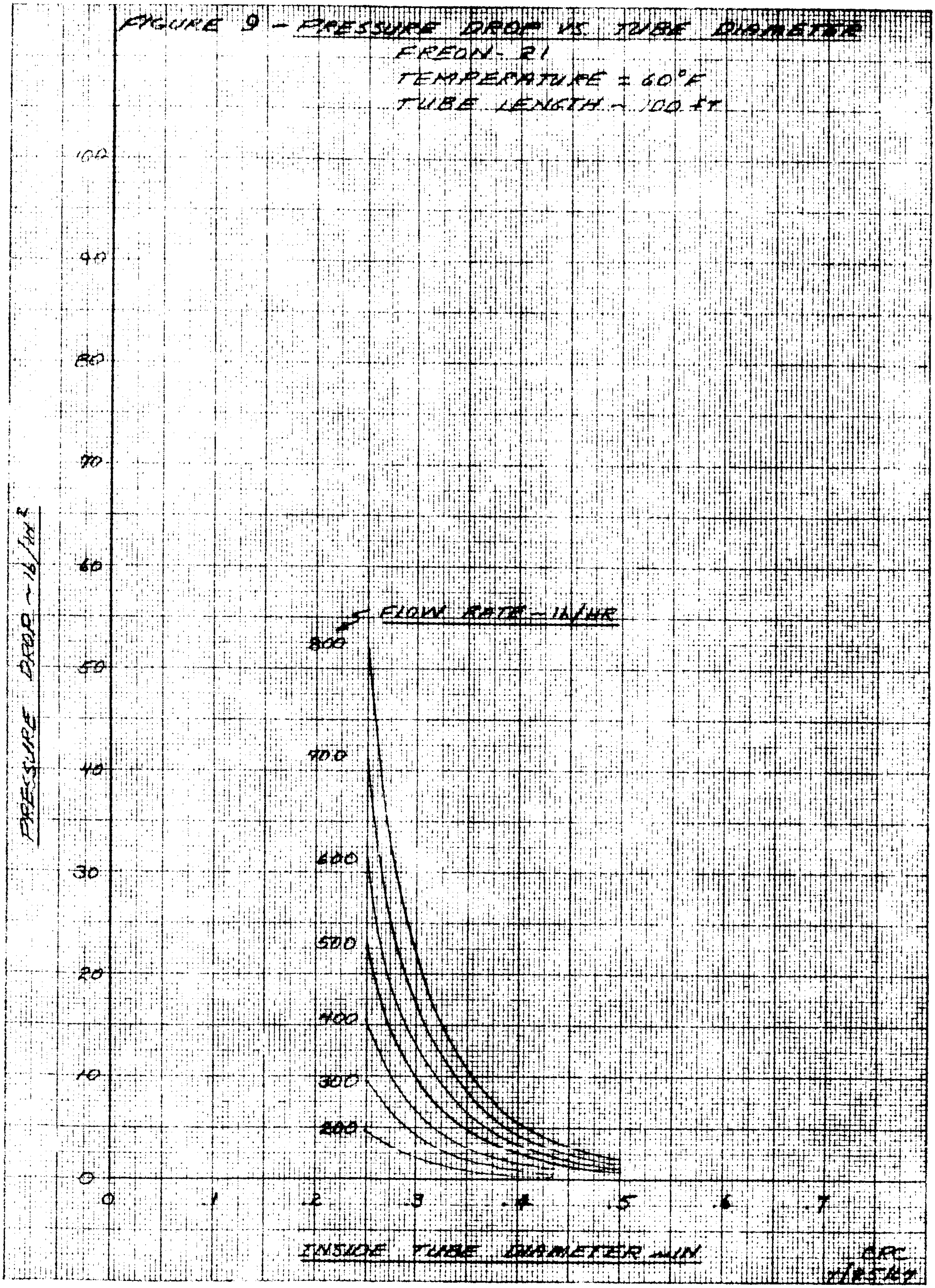
FIGURE 9 - PRESSURE DROP VS. TUBE DIAMETER
FREON-21
TEMPERATURE = 60°F
TUBE LENGTH ~ 100 FT
FLOW RATE ~ lb/HR
800
700
600
500
400
300
200
PRESSURE DROP ~ lb/in²
INSIDE TUBE DIAMETER ~ IN

PR 29-25

STRESS ANALYSIS REPORT

AAP/PIP EARLY APPLICATIONS

Contract NAS8-21004

9 September 1967

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LIST OF TABLES

1.0 INTRODUCTION

1.1 Purpose of Report - This report summarizes the preliminary stress analysis performed on the carrier configuration selected as a result of the trade study conducted and reported in PR 29-7 dated 23 August 1967.

1.2 Description of Carrier - The carrier is a truncated conical pressurizable chamber closed at the larger end by a spherical cap and interfacing with the CM via a docking collar at the smaller end. During boost into orbit the carrier is supported in the SLA of the SIB by a space framework which also provides support for experiments and equipment not required to be inside the pressurized volume as well as stabilizing the SLA. The carrier is illustrated in Figure 1.

2.0 SUMMARY

The analysis summarized in this report represents the first iteration in the engineering design process. All primary structure was examined as well as key items of secondary structure. The member sizes developed at this stage will form the basis of the structural model used to develop more accurate loads. Results of computer analysis of the basic structure for boost, docking and lateral stiffness are shown as well as the analysis of key detail.

3.0 DISCUSSION

3.1 Loads and Materials

3.1.1 *Inertia Loads - Boost Phase

**Condition 1 - Stage I Burn Out
N_z = -6.92 g's limit, -9.7 g's ult (aft)
$N_x = N_y = 0$

***Condition 2 - Post Release
N_z = -4.5 g's limit, -6.3 g's ult (aft)
N_x = 3.75 g's limit, 5.25 g's ult

***Condition 3 - Post Release
N_z = -4.5 g's limit, -6.3 g's ult
N_y = 3.75 g's limit, 5.25 g's ult

*Includes a 1.5 dynamic amplification factor.
** Ref. Chrysler TN-AP-67-173
*** Based on Data in NASA-MSC RFO BG 681 and Boeing Document D2-84007-1

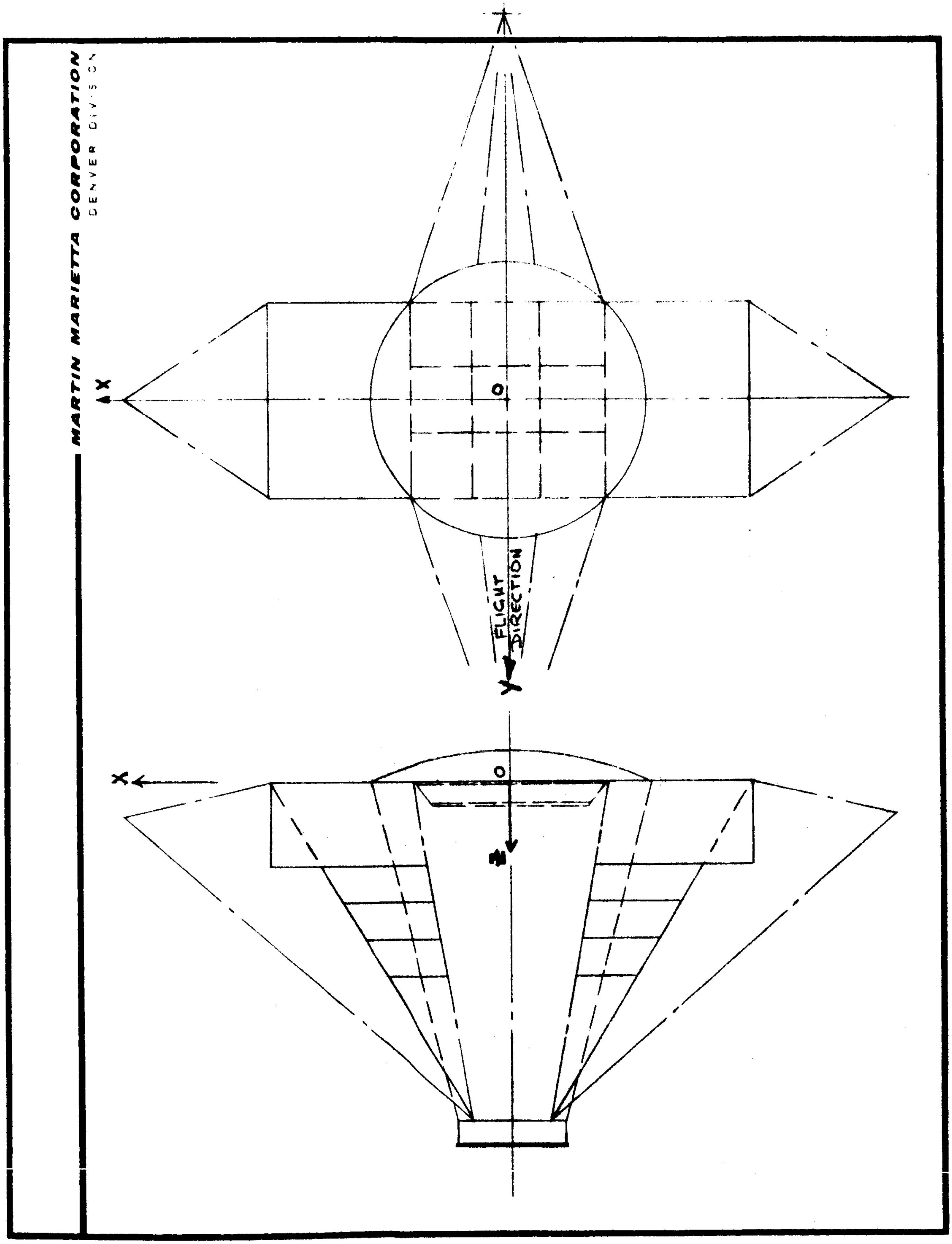

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FIGURE 1 - STRUCTURAL CONFIGURATION - AAP/PIP EARLY APPLICATIONS CARRIER

3.1.2 Pressurization

*Condition 4 - Operating pressure = 5.2 psi

Proof pressure = 9.5 psi

Ultimate pressure = 12.9 psi

* Ref. Command Module Design Pressures

3.1.3 *Transposition Docking

Condition 5 - Axial Load = 2610# LL (Compression)

Lateral Load = 2600# LL

Moment = 30840# LL

*Ref. NAA Document MH01-05050-414

3.1.4 Lateral Stiffness

Condition 6 - The carrier is required to furnish a structural stiffness between diametrically opposed SLA hardpoints of 50,000 lb/in. (Ref. NASA-MSC RFP BG-681)

3.1.5 Materials - The basic structural material for the carrier is 2219 aluminum alloy. It was selected because of its favorable welding and strength characteristics. Other higher strength materials, e.g., stainless steel, titanium, were considered but stability, handling and manufacturing considerations indicate that the thicker gages in aluminum are more practical. Physical properties used in this analysis are:

*F_{tu} = 62000 psi
F_{ty} = 50000 psi
F_{cy} = 50000
$E = 10.5 (10^6)$ psi

$G = 4.0 (10^6)$ psi

*NOTE: In order to hold a 1.15 margin on yield, a F_{tu} value of 60800 psi should be used. These values are for sheet and plate in the T-87 temper. Subsequent analysis will reflect extruded tube allowables as well.

3.2 Analysis

3.2.1 Computer Analysis of Basic Structure for Inertia Loading

3.2.1.1 Discussion

The basic structure was analyzed for strength and stiffness requirements using the idealized structure shown on Figure 2. The structure geometry is described by the coordinates given in Table 1. A Martin developed computer program utilizing the IBM 1130 computer was used to analyze the structure. All members are considered to be axially loaded with pinned ends except for the upper ring structure. The ring was subdivided into equivalent chord members which have axial stiffness, torsional stiffness and bending stiffness about both axes. The pressure shell and sheet metal skin of the external equipment support structure are not included as structural elements in the computer analysis of the basic structure, but are treated in other sections of this report.

The basic structure consists of 2219 aluminum alloy square tubes. Tube configurations are described in Table 2. Critical buckling load curves were plotted for various tube configurations. See Figure 3.

Weights for the structure, experiments, and subsystems were distributed to the node points as shown in Table 3. The battery support structure was idealized as discussed in Section 3.2.3. A computer solution of this structure was made and the calculated reactions were applied as loads to the applicable node points of the basic structure. Structural and experiment weights were distributed to the flight vehicle node points by means of hand calculations. Three loading conditions were evaluated as shown in Table 4.

The member loads obtained from the computer runs are tabulated in Table 5 along with member allowable loads and margins of safety.

3.2.1.2 Machine Program - The program is designed for solving highly redundant structures using the direct stiffness method. Any type of structure may be analyzed within the limitation of the program, provided a stiffness matrix is available for each discrete element used to idealize the structure. The three steps required to solve a complex structural problem are idealizing the structure, tabulating the input data, and performing the basic matrix operations with the computer.

3.2.1.2 Machine Program - (Continued)

For a given problem, 600 degrees of freedom may be considered. The program automatically assigns six degrees of freedom to each node point, which limits its capacity to 100 node points. Experience has shown that this procedure eliminates many input errors. The program is designed to perform matrix operations in sparse matrix rotation, i.e., only the nonzero elements are stored or manipulated.

Elemental stiffness matrices available include:

Axial members
Torque tubes
Straight or tapered beams

ANALYSIS OF

AAP/PIP Mission 1A Structure

3.2.1.3

Computer Structural Model

Legend:

⑥ = Node Point

6 = Member No.

—— = Actual Member

– – – = Axial member equivalent to rectangular plate

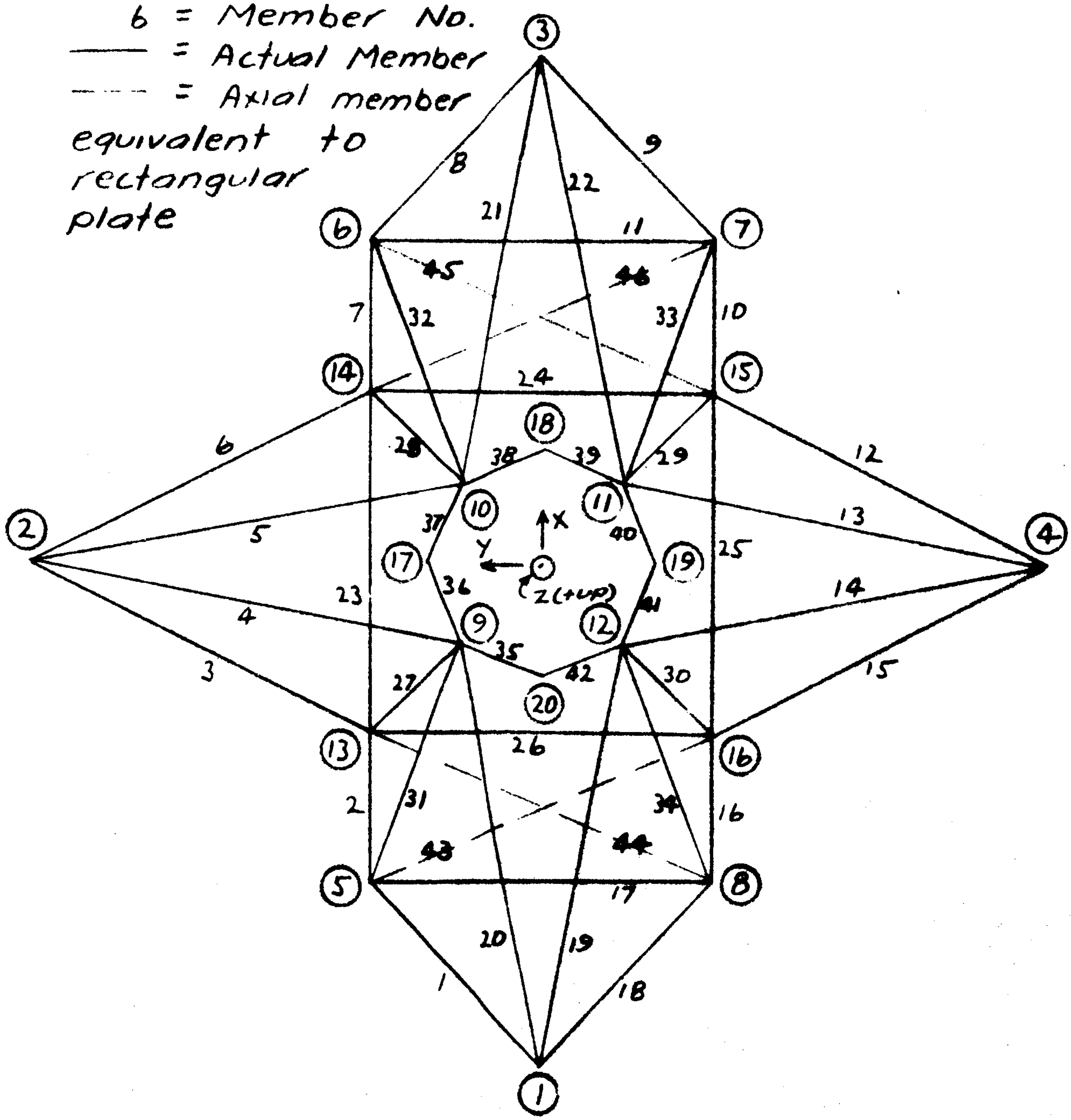
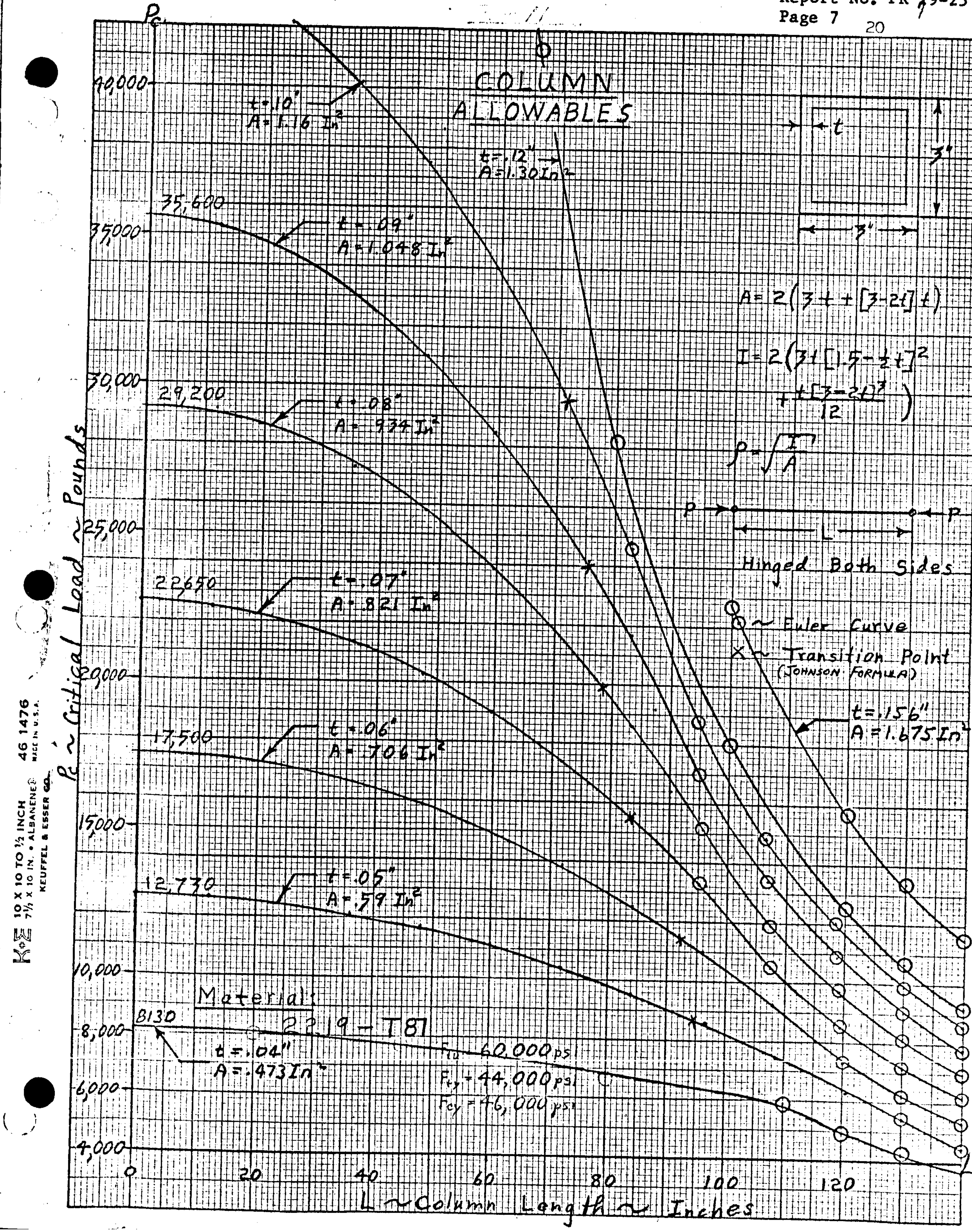


Figure 2


COLUMN ALLOWABLES
Pc
P ~ Critical Load ~ Pounds
L ~ Column Length ~ Inches
40,000
35,000
30,000
25,000
20,000
15,000
10,000
8,000
6,000
4,000
0
20
40
60
80
100
120
35,600
29,200
22,650
17,500
12,730
8130
t = .10"
A = 1.16 In²
t = .12"
A = 1.30 In²
t = .09"
A = 1.048 In²
t = .08"
A = .934 In²
t = .07"
A = .821 In²
t = .06"
A = .706 In²
t = .05"
A = .59 In²
t = .04"
A = .473 In²
t = .156"
A = 1.675 In²
t
3"
3"
A = 2(3t + [3-2t] t)
I = 2(3t [1.5 - ½t]² + t[3-2t]³/12)
ρ = √(I/A)
P
L
P
Hinged Both Sides
O ~ Euler Curve
X ~ Transition Point (JOHNSON FORMULA)
Material:
2219 - T87
Ftu = 60,000 psi
Fty = 44,000 psi
Fcy = 46,000 psi
K+E 10 X 10 TO ½ INCH 46 1476
7½ X 10 IN. • ALBANENE®
MADE IN U.S.A.
KEUFFEL & ESSER CO.

ANALYSIS OF AAP/PIP Mission 1A Structure

3.2.1.3

Node Point Coordinates

Table 1

Node Point	X	Y	Z
1	-116.	0.	10.
2	0.	116.	10.
3	116.	0.	10.
4	0.	-116.	10.
5	-75.	29.7	0.
6	75.	29.7	0.
7	75.	-29.7	0.
8	-75.	-29.7	0.
9	-11.68	11.68	102.5
10	11.68	11.68	102.5
11	11.68	-11.68	102.5
12	-11.68	-11.68	102.5
13	-29.7	29.7	0.
14	29.7	29.7	0.
15	29.7	-29.7	0.
16	-29.7	-29.7	0.
17	0.	16.5	102.5
18	16.5	0.	102.5
19	0.	-16.5	102.5
20	-16.5	0.	102.5

Ref. Figure 1 for axis orientation. Note that this coordinate system is not the same as the CSM coordinate system. This system was used for the stress analysis computer program only.

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ANALYSIS
OF
AAP/PIP Mission 1A Structure

3.2.1.3
Member Configuration

Table 2

Member	Configuration	Area (in^2)
1, 8, 9, 18	Tube 3" × 3" × .04"	.473
2, 7, 10, 16	Tube 3" × 3" × .05"	.59
3, 6, 12, 15	Tube 3" × 3" × .08"	.934
4, 5, 13, 14, 19, 20, 21, 22	Tube 3" × 3" × .156"	1.675
11, 17	Tube 3" × 3" × .04"	.473
23, 24, 25, 26	Tube 3" × 3" × .08"	.934
27, 28, 29, 30	Undefined	.5
31, 32, 33, 34	Undefined	.3
35, 36, 37, 38, 39, 40, 41, 42	Undefined Required I major axis = 13. in^4 Required I minor axis = .5 in^4	.4

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ANALYSIS
OF
AAP/PIP Mission 1A Structure

3.2.1.4
Weight Distribution For Static Analysis

Table 3

Node Point	Experiment Weight	Sub-Systems Weight	Structures Weight	Total Weight
5	146	69	21	236
6	104	75	21	200
7	116	76	21	213
8	234	49	21	304
9		192	115	307
10		163	115	278
11		184	115	299
12		179	115	294
13	91	495	129	715
14	66	491	129	686
15	96	490	129	715
16	165	479	129	773

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ANALYSIS
OF
AAP/PIP Mission 1A Structure

3.2.1.5
Node Point Loading (Limit)

Table 4

Node Pt.	Wt.	Case 1 $N_x = 0$ $N_y = 0$ $N_z = -6.92$			Case 2 $N_x = 3.75$ $N_y = 0$ $N_z = -4.5$			Case 3 $N_x = 0$ $N_y = 3.75$ $N_z = -4.5$		
		P_x	P_y	P_z	P_x	P_y	P_z	P_x	P_y	P_z
5	236	-303	198	-1639	1171	-79.3	-132	-1150	1931	-2361
6	200	300	191	-1389	1374	317	-1756	1157	975	-2220
7	213	306	-196	-1471	1448	-325	-1851	-721	559	293
8	304	-288	-186	-2108	1440	88.0	-448	807	2166	-6.4
9	307	-344	114	-2125	285	90.5	-1317	157	819	-728
10	278	272	116	-1925	681	57.7	-1338	-203	754	-604
11	299	328	-108	-2067	713	-57.6	-1408	550	641	-1922
12	294	-302	-126	-2036	319	-102	-1240	-619	629	-2048
13	715	621	376	-4951	3215	206	-4228	99.7	2070	-2780
14	686	-595	318	-4754	2327	-145	-2164	-85.7	1993	-2669
15	715	-610	-342	-4953	2422	153	-2244	-697	2042	-3640
16	773	-615	-36.8	-5354	3431	-203	-4474	704	2246	-3916

All node point loads include a dynamic amplification factor of 1.5

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ANALYSIS
OF
AAP/PIP Mission 1A Structure

3.2.1.6
Tabulation of Member Critical Loads
Table 5

Member	Length (in)	Area (in^2)	Ultimate Load (lb)	Allowable Ultimate Load (lb)	Ultimate M.S.
1, 8, 9, 18	51.6	.473	5,800C	7,520C	.30
2, 7, 10, 16	45.3	.59	8,940C	11,800C	* .32
3, 6, 12, 15	91.8	.934	15,200C	16,400C	.08
4, 5, 13, 14, 19, 20, 21, 22	139.9	1.675	9,750C	11,550C	.19
11, 17	59.4	.473	4,490C	7,310C	* .63
23, 24, 25, 26	59.4	.934	14,350C	23,800C	* .66
27, 28, 29, 30	105.6	.5	8,120T	31,000T	Large
31, 32, 33, 34	121.8	.3	2,010T	18,600T	Large
35, 36, 37, 38, 39, 40, 41, 42	12.63	A = .4 I_{major} = 13. I_{minor} = .5	See Section 3.2.5.10		

* Margins shown are for axial loads only. See Section 3.2.6 for beam-column margins

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3.2.2 Computer Analysis of Basic Structure for Transposition Docking

3.2.2.1 Discussion

The basic structure defined in Section 3.2.1.3 was used in the transposition docking analysis. Preliminary transposition docking loads were calculated using North American Aviation Document MH01-05050-414. The three point loading shown in this document was considered to be transferred by the docking collar to the four upper longeron points of the structural model. The calculated interface loads are shown in Table 6.

The critical member loads shown in Table 7 were tabulated from the computer run. The structural model is shown in Figure 4.

ANALYSIS
OF
AAP/PIP Mission 1 A Structure

3.2.2.2

Computer Structural Model

Legend:
(6) = Node Point
6 = Member No.
—— = Actual Member
- - - = Axial member equivalent to rectangular plate

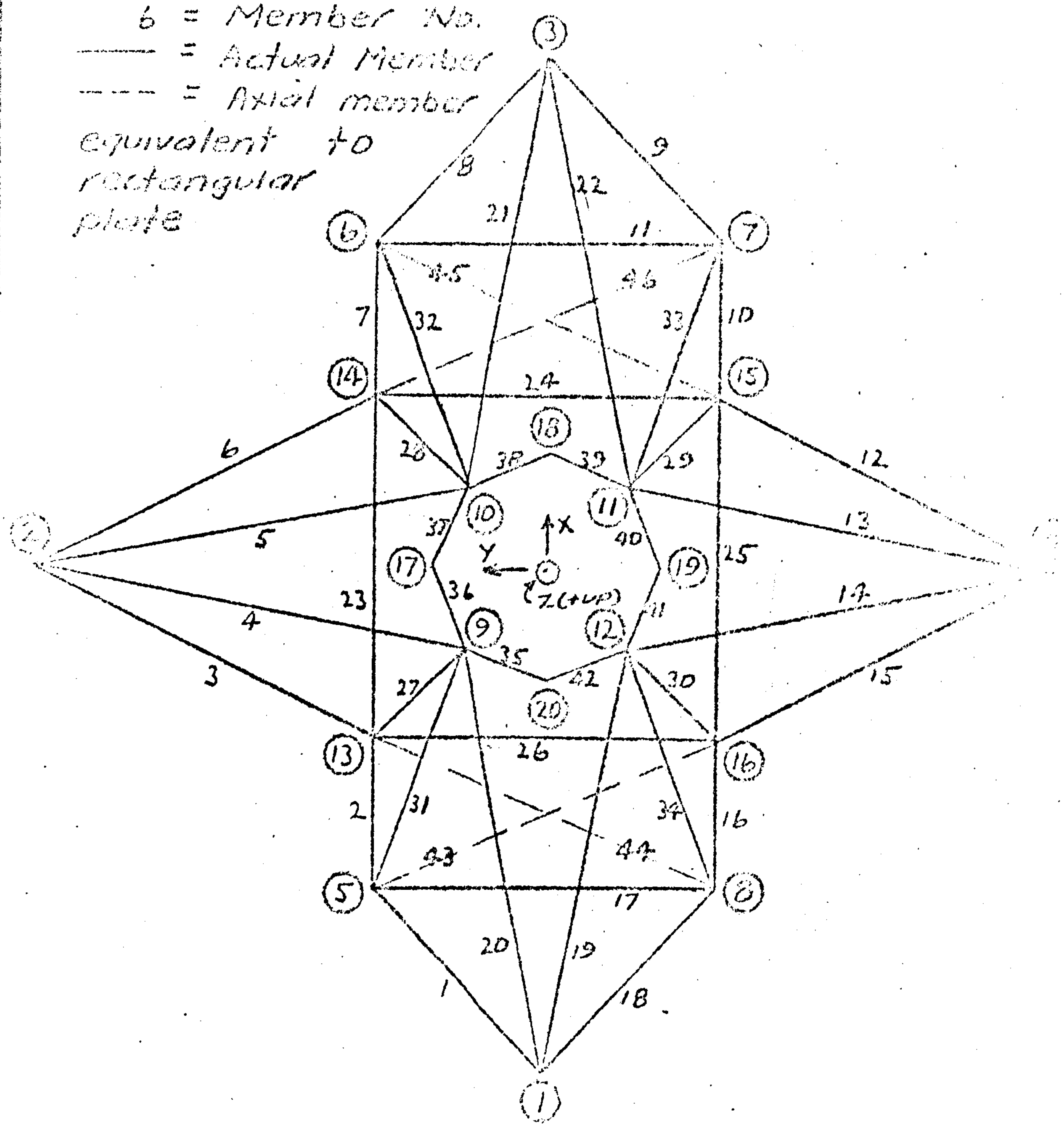

Figure 4

BY: J.RT CHECKED BY: REVISED BY:

ANALYSIS
OF
AAP/PIP Mission 1A Structure

3.2.2.3
Node Point Loading

Node Point	P_x	P_y	P_z
9	643[a]	-643[a]	395[a]
10	643	-643	-915
11	643	-643	-2225
12	643	-643	-915

TABLE 6

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ANALYSIS OF AARIDIO MISSION IA Structure

3.3.4

Maximum Member Loads TABLE 7

Member	Length (in)	Area (in^2)	Ultimate Load (lb)	Allowable Ultimate Load (lb)	Ultimate M.S.
1, 8, 9, 18	51.6	.473	1,267 C	7,520 C	Large
2, 7, 10, 16	45.3	.59	1,526 C	11,800 C	Large
3, 6, 12, 15	91.8	.934	2,021 C	16,400 C	Large
4, 5, 13, 14, 19, 20, 21, 22	139.9	1.675	1,643 C	11,550 C	Large
11, 17	59.4	.473	823 C	7,310 C	Large
23, 24, 25, 26	59.4	.934	1,442 C	23,800 C	Large
27, 28, 29, 30	105.6	.5	345	1,500	Large
31, 32, 33, 34	121.8	.3	506	1,130	Large
35, 36, 37, 38, 39, 40, 41, 42	12.63	A = .4 I_{major} = 13. I_{minor} = .5			Large

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3.2.3 Computer Analysis of Battery Support Structure

3.2.3.1 Discussion

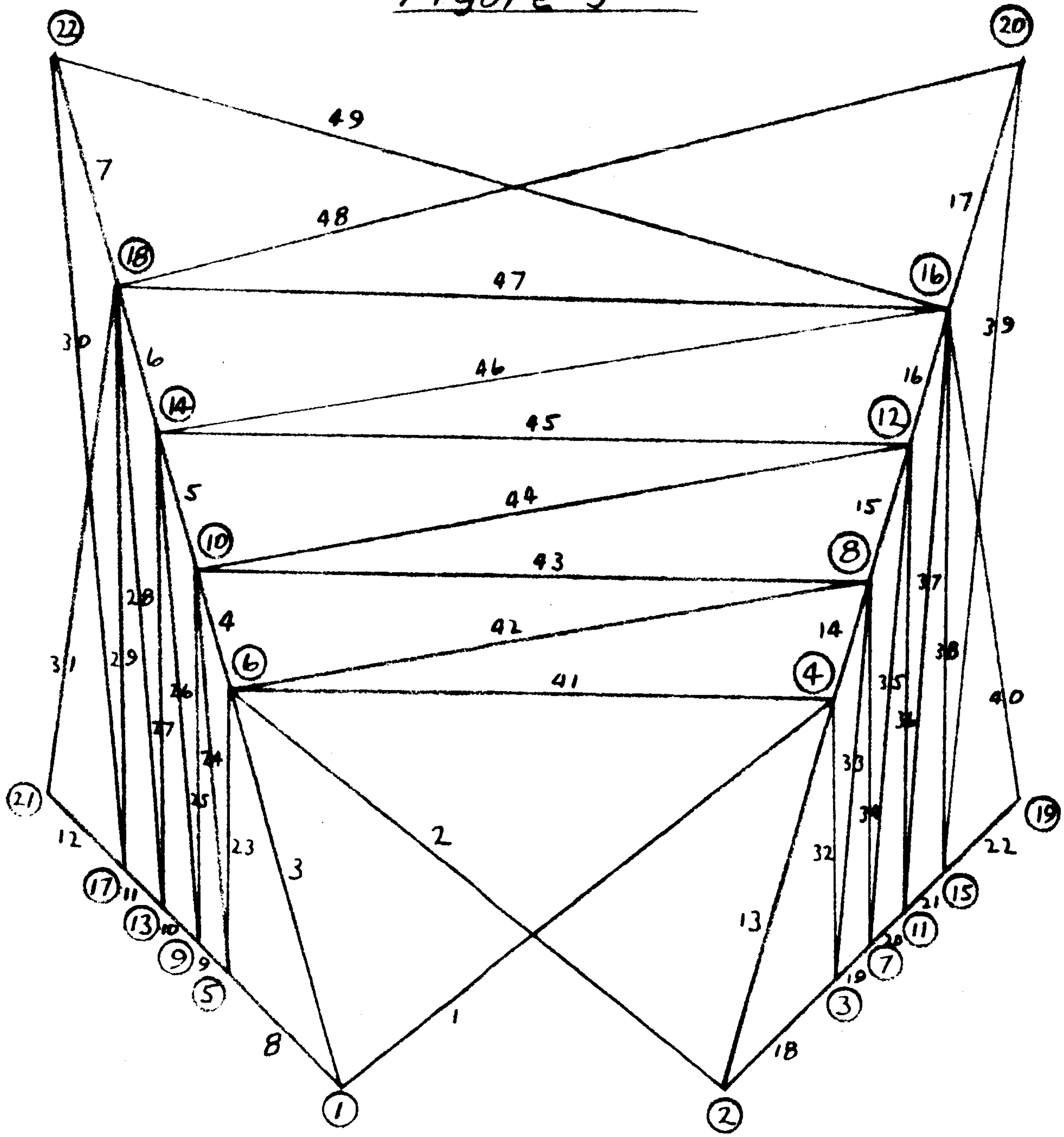
The two battery support structures were analyzed independently of the basic structure. Since the two structures are identical in configuration it was possible to analyze one structure with two different sets of loads. The computer program discussed in Section 3.2.1 was used to determine number loads and reactions at the basic structure interface points.

Figure 5 shows the idealized structural model with node point coordinates given in Table 8. The structure is made up of pinned end members, some of which are the equivalent in stiffness of the skin panels. The equivalent member loads are used to analyze selected panels as shown in Section 3.2.5.9. Loads and margins of safety for the axial members are shown in Section 3.2.1.6. Weights and loads from the batteries were distributed to the node points as shown in Table 9. Critical member loads are shown in Table 10.

It is considered that the separate battery support structure analysis gives internal loads which are approximately the same as if the battery support structure and the basic structure were analyzed as an entire unit. The battery support structure reaction points were considered fixed which is an approximation. The member sizes obtained from the separate analyses will be used for a first iteration for a larger computer solution which will include both structures acting together.

ANALYSIS
OF
AAP/RIP Mission 1A Structure

3.2.3.2
Computer Structural Model
Figure 5



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ANALYSIS
OF
AAP/PIP Mission IA Structure

3.2.3.2

Node Point Coordinates

Table 8

Node Point	X	Y	Z
1	11.68	11.68	102.5
2	11.68	-11.68	102.5
3	19.5	-19.5	58.75
4	38.5	-19.5	58.75
5	19.5	19.5	58.75
6	38.5	19.5	58.75
7	20.2	-20.2	47.5
8	45.	-20.2	47.5
9	20.2	20.2	47.5
10	45.	20.2	47.5
11	23.5	-23.5	36.25
12	52.	-23.5	36.25
13	23.5	23.5	36.25
14	52.	23.5	36.25
15	25.2	-25.2	25.
16	59.	-25.2	25.
17	25.2	25.2	25.
18	59.	25.2	25.
19	29.7	-29.7	0.
20	75.	-29.7	0.
21	29.7	29.7	0.
22	75.	29.7	0.

ANALYSIS OF

AAP/PIP Mission 1A Structure

3.2.3.3

Node Point Loading (Limit)

Table 9

Node pt.	−X Side							+X Side						
	Wt.	L.C.1	L.C.2		L.C.3			Wt.	L.C.1	L.C.2		L.C.3		
		Z	X	Z	X	Y	Z		Z	X	Z	X	Y	Z
3	6.79*	-47.		-30.6			-30.6	4.45*	-30.8		-20.			-20.
4	13.08	-90.5	-74.5	-58.8	21.3	-74.5	-58.8	7.67	-53.1	45.5	-34.5	-10.1	45.5	-34.5
5	4.83	-33.4		-21.7			-21.7	1.06	-7.4		-4.8			-4.8
6	9.3	-64.4	-53.	-41.8	-21.3	-53.	-41.8	1.82	-12.6	10.8	-8.2	10.1	10.8	-8.2
7	15.	-104.		-67.5			-67.5	14.25	-98.6		-64.			-64.
8	25.	-173.	-150.	-112.5	70.5	-150.	-112.5	21.65	-150.	134.5	-97.5	-62.6	134.5	-97.5
9	15.	-104.		-67.5			-67.5	11.55	-80.		-52.			-52.
10	25.	-173.	-150.	-112.5	-70.5	-150.	-112.5	17.55	-121.5	109.	-79.	62.6	109.	-79.
11	51.5	-356.		-232.			-232.	51.5	-356.		-232.			-232.
12	88.5	-613.	-525.	-398.	117.5	-525.	-398.	88.5	-613.	525.	-398.	-117.5	525.	-398.
13	51.5	-356.		-232.			-232.	51.5	-356.		-232.			-232.
14	88.5	-613.	-525.	-398.	-117.5	-525.	-398.	88.5	-613.	525.	-398.	117.5	525.	-398.
15	100.	-693.		-450.			-450.	100.	-693.		-450.			-450.
16	136.	-942.	-885.	-612.	504.	-885.	-612.	136.	-942.	885.	-612.	-504.	885.	-612.
17	100.	-693.		-450.			-450.	100.	-693.		-450.			-450.
18	136.	-942.	-885.	-612.	-504.	-885.	-612.	136.	-942.	885.	-612.	504.	885.	-612.

Load Case Definition:

L.C.1: $N_x = 0$, $N_y = 0$, $N_z = -6.92$

L.C.2: $N_x = 3.75$ $N_y = 0$, $N_z = -4.5$

L.C.3: $N_x = 0$, $N_y = 3.75$ $N_z = -4.5$

All loading cases include a dynamic amplification factor of 1.5.

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ANALYSIS OF AAP/PIP Mission 1A Structure

3.2.3.4
Tabulation of Member Critical Loads

Table 10

Member	Length	Ultimate Axial Load
1, 2	60.05"	1000# T, 906# C
3, 13	51.91	606 T
4, 14	13.01	470 C
5, 15	13.65	714 C
6, 16	13.36	1270 C
7, 17	30.02	1940 C
8, 18	45.13	1415 T
9, 19	11.29	1310 T
10, 20	12.18	1070 T
11, 21	11.50	396 T
12, 22	25.80	704 C
23, 32	19.00	153 C
24, 33	27.88	171 T
25, 34	24.80	426 C
26, 35	33.89	165 C
27, 36	28.50	1450 C
28, 37	37.28	562 C
29, 38	33.80	580 C
30, 39	55.90	720 T
31, 40	38.78	2080 C
41	39.00	395 C
42	41.77	745 C
43	40.40	264 C
44	45.66	79 C
45	47.00	718 C
46	50.47	1360 C
47	50.40	508 C
48, 49	62.41	1675 T, 2180 C

C = compression
T = tension

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3.2.4 Computer Analysis of Beam-Columns - Certain members of the carrier structure carry lateral loads as well as axial loads shown in Sections 3.2.1 and 3.2.2. These members were analyzed as beam-columns using the machine program described below.

3.2.4.1 Beam Column Computer Program - This Martin developed program for the IBM 1130 computer uses an iteration procedure to calculate moments due to axial and lateral loads in a beam column. The member can be subdivided into as many as 40 segments which allows the use of varying area and moment of inertia. Lateral load types include uniform load, triangular load distribution, concentrated load at any point, applied moment at any point, and zero lateral load with initial column eccentricity. Any combination of the above types can be used.

A double integration procedure is used to calculate lateral deflections which are subsequently used to calculate total moment in the member. The program will iterate until the nth secondary moment is less than 1/2 percent of the total accrued moment or until 50 iterations have been completed. The program checks for stability by determining if the secondary moments converge to the desired accuracy within 50 iterations.

Stresses within each segment of the member are calculated and compared to allowable panel crippling stresses. Margins of safety are obtained by increasing the applied axial and lateral loads by a factor until failure is incipient. This factor determines the margin of safety, i.e., MS= Factor -1.

3.2.5 Lateral Stiffness Analysis

3.2.5.1 Discussion

The stiffness analysis was performed using the basic structure defined in Section 3.2.1.3. Unit loads acting in opposite directions were applied at diametrically opposite node points. Deflections at the loaded node points were obtained from the computer program. The structural model is shown in Figure 6.

ANALYSIS
OF
AAP/PIP Mission 1A Structure

3.2.5.2

Computer Structural Model

Legend:
(6) = Node Point
6 = Member No.
—— = Actual Member
- - - = Axial member equivalent to rectangular plate

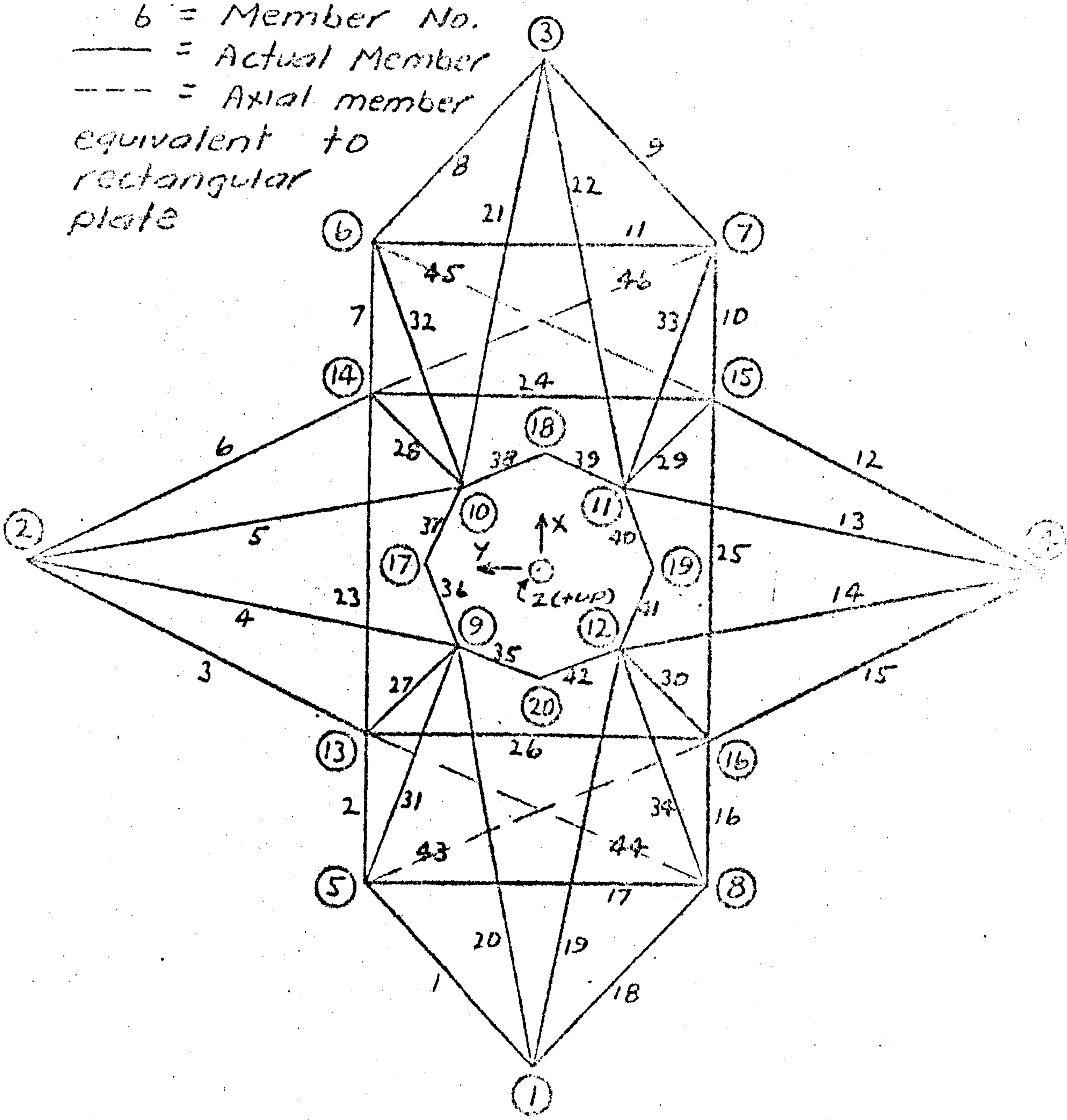

Figure 6

ANALYSIS
OF
AAP/PIP Mission 1A Structure

3.2.5.3
Node Point Loading

TABLE 11

Node Point	X Direction Stiffness			Y Direction Stiffness		
	X	Y	Z	X	Y	Z
1	1#	0	0	0	0	0
2	0	0	0	0	1#	0
3	-1#	0	0	0	0	0
4	0	0	0	0	-1#	0

3.2.6.4
Stiffnesses

X direction 50,300 lb/in

Y direction 93,000 lb/in

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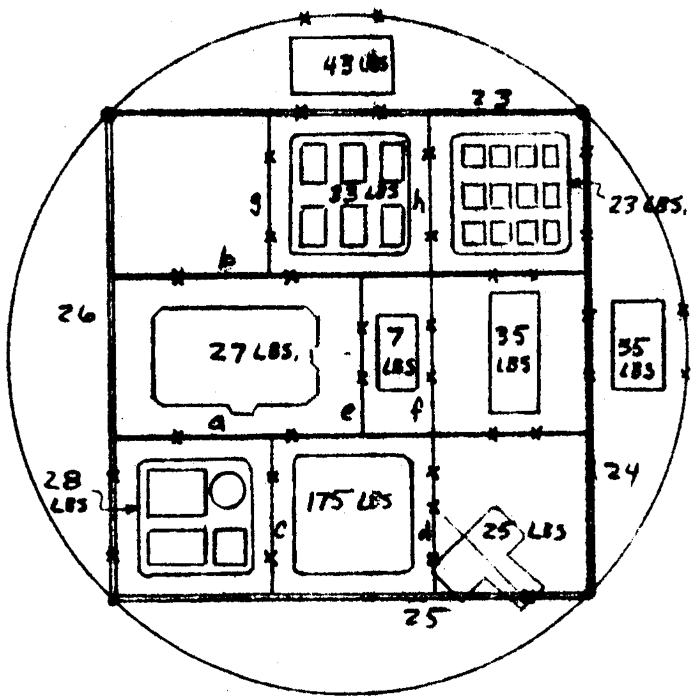
3.2.6 Detail Parts Analysis - This section contains summaries of the analysis performed on key details of the carrier structure.

ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE

3.2.6.1

PART DESCRIPTION INTERNAL EXPERIMENT SUPPORT STRUCTURE

CRITICAL CONDITION



NOTES
X DENOTES SUPPORT POINTS

NUMBERS REFER TO MEMBERS

VIEW LOOKING AFT

DISCUSSION

MEMBERS 23,24,25,26 ARE PRIMARY TRUSS MEMBERS THEY CARRY PRIMARY STRUCTURE LOADS AS WELL AS LOCAL EQUIPMENT LOADS.

MEMBERS a,b ARE SECONDARY MEMBERS CARRYING MAJOR PORTIONS OF EQUIPMENT LOADS.

MEMBERS c,d,e f,g,h ARE LOCAL MEMBERS TO TRANSMIT EQUIPMENT LOADS TO PRIMARY & SECONDARY STRUCTURE.

ALL MATERIAL ~ 2219-T87 ALUM ALLOY

PREPARED BY ___ CHECKED BY ___ REVISED BY ___

ANALYSIS OF AAP/PIP MISSION 1A STRUCTURE

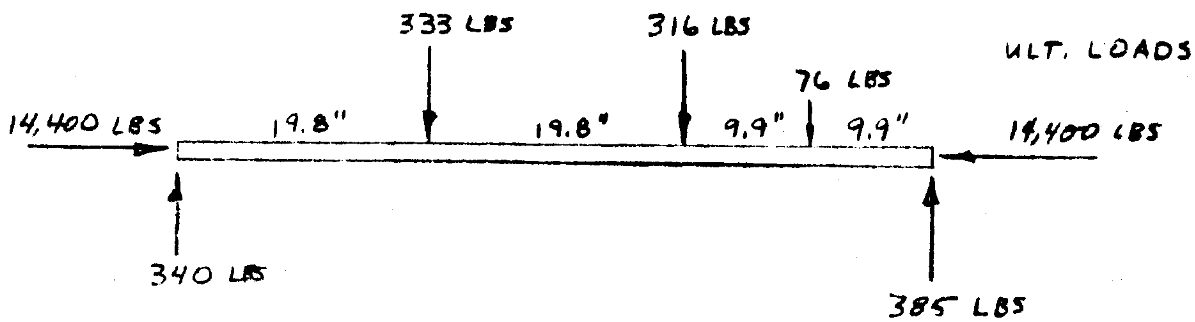
3.2.6.1

PART DESCRIPTION

PRIMARY TRUSS MEMBER

CRITICAL CONDITION

CASE NO. 3 - 4.5 g's AFT, 3.75 g's LATERAL (Y-DIRECTION)



DISCUSSION

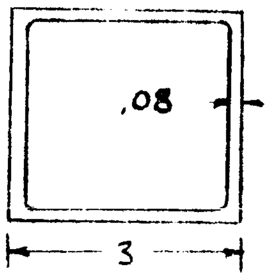
MEMBER NO. 25 IS CRITICAL, AS IT SUPPORTS RELATIVELY HEAVY EQUIPMENT, IT IS CRITICAL AS A BEAM COLUMN IN THE LONGITUDINAL PLANE. IT IS ASSUMED TO BE SUPPORTED LATERALLY BY EQUIPMENT AND OTHER SECONDARY STRUCTURE IN THE LATERAL PLANE.

PREPARED BY________ CHECKED BY________ REVISED BY________

**ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE**

3.2.6.1

MEMBER NO. 25



$A = .934 \text{ IN}^2$
$I = 1.34 \text{ IN}^4$

THE ANALYSIS WAS PERFORMED BY A BEAM-COLUMN COMPUTER PROGRAM.

RESULTS: MAX MOMENT = 11,260 IN LBS

MAX STRESS = 28,020 PSI (COMPR)

ALLOWABLE STRESS = 32,660 PSI (CRIPPLING)

MARGIN OF SAFETY = +.12

NOTE: COMPUTER RUN CONVERGED IN 6 ITERATIONS. THE MEMBER IS NOT STABILITY CRITICAL. THIS MEMBER MAY NOT REMAIN A SQUARE TUBE, DESIGN CONSIDERATIONS COULD REQUIRE SOME OTHER SECTION, BUT THIS WORK WILL YIELD GOOD WEIGHT VALUES.

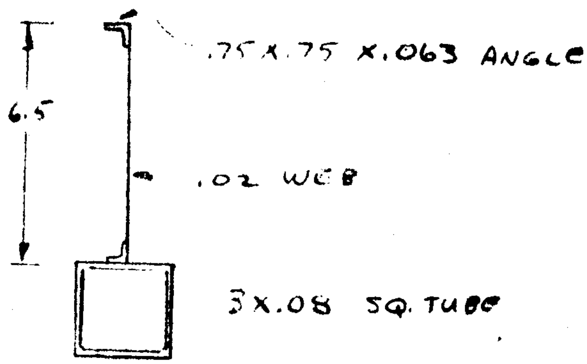
DEN 65098 (3-56)

PREPARED BY________ CHECKED BY________ REVISED BY________

3.2.6.1

MEMBER NO. 25 (WITH EXPERIMENT SUPPORT STRUCTURE)

THE BOX-TYPE EXPERIMENT SUPPORT STRUCTURE IS ATTACHED TO MEMBER 25 AND SERVES A FUNCTIONAL PURPOSE. THE COMBINED STRUCTURE WAS CHECKED AS A BEAM-COLUMN FOR THE SAME LOADS SHOWN PREVIOUSLY.



$A = 1.212$ IN^2
$I = 8.673$ IN^4

RESULTS: MAX MOMENT = 7,100 IN LBS

MAX STRESS = 17,020 PSI

ALLOWABLE STRESS = 33,000 PSI
(CRIPPLING)

MARGIN OF SAFETY = +.86

NOTE: COMPUTER RUN CONVERGED IN 3 ITERATIONS. THE MEMBER IS NOT STABILITY CRITICAL.

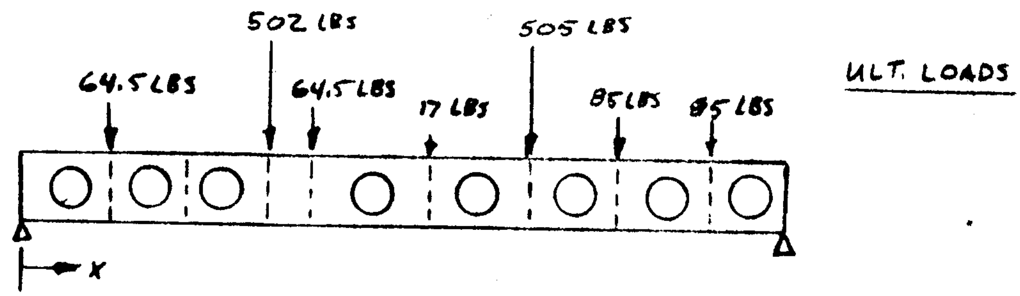
ANALYSIS OF AAP/PIP MISSION 1A STRUCTURE

3.2.6.1

PART DESCRIPTION SECONDARY EXPERIMENT SUPPORT BEAM MEMBER (a)

CRITICAL CONDITION

CASE NO. 1 4.62 g's AFT



P	X
64.5	8.
502	19.8
64.5	22.5
17.	32.
505	39.6
85.	46.5
85.	54.

DISCUSSION

MEMBER (a) IS CRITICAL AS A BEAM. IT IS MADE UP OF ANGLE CAPS AND SHEET WEB.

THE UPPER CAP IS CRITICAL AS A COMPRESSION MEMBER WHEN BENDING LOAD IS EXPERIENCED IN THE BEAM. THE WEB IS SHEAR STABILIZED BY FLANGED LIGHTENING HOLES AND SMALL STIFFENERS.

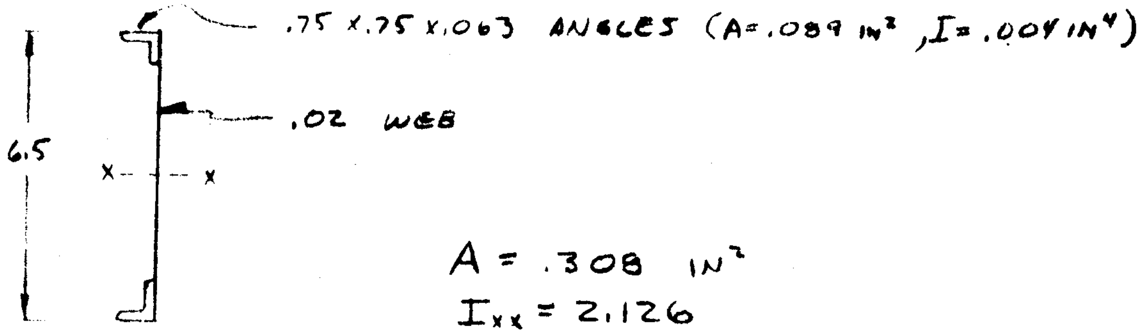
GEN 965098 (3-56)

PREPARED BY________ CHECKED BY________ REVISED BY________

ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE

3.2.6.1

MEMBER (a)



$A = .308 \text{ IN}^2$

$I_{xx} = 2.126$

MAX MOMENT = 12,220 IN LBS ULT

$$f_b = \frac{Mc}{I} = \frac{12{,}220(3.25)}{2.126} = 18{,}700 \text{ PSI}$$

LATERAL COLUMN STABILITY CHECK ($L_{max} = 11.8$ IN)

$$F_c = \frac{\pi^2 EI}{L^2 A} = \frac{\pi^2 (10.5\times10^6)(.004)}{(11.8)^2(.089)} = 33{,}500 \text{ PSI}$$

CRIPPLING CHECK

$$\frac{b}{t} = \frac{.719}{.063} = 11.4$$

$F_{cc} = 33{,}000$ PSI

$$M.S. = \frac{33{,}000}{18{,}700} - 1 = +.76$$

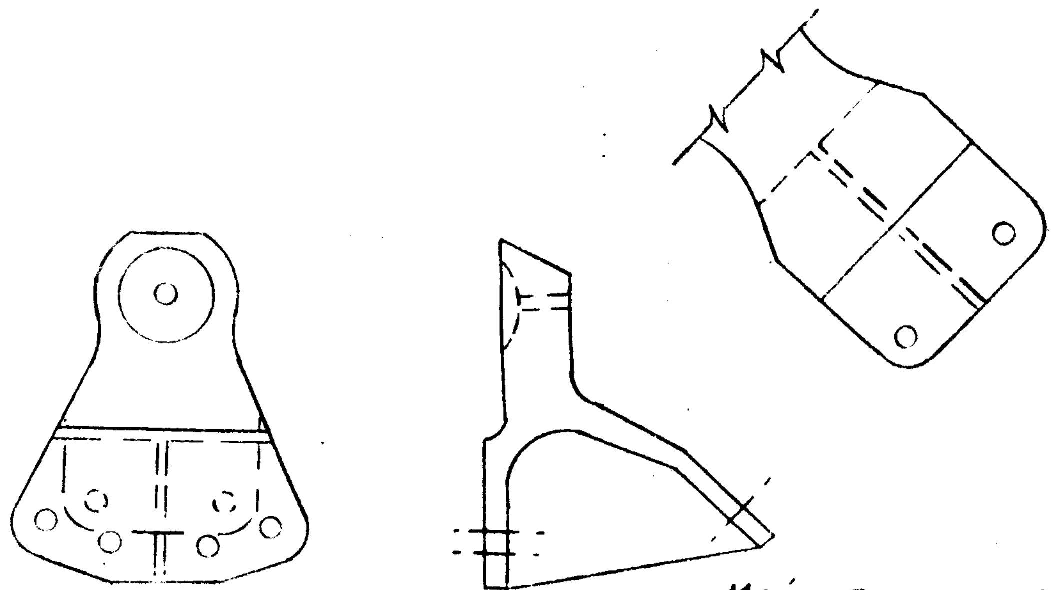
DEN 065098 (3-56)

PREPARED BY ______ CHECKED BY ______ REVISED BY ______

**ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE**

PART DESCRIPTION SLA HARD POINT PICKUP FITTINGS
(NODE POINTS (D & (4)))

CRITICAL CONDITION MEMBERS 3, 6, 13, 14
1130 RUN #2, LOAD CASE #2



MAT'L: 7075-T73 HAND FORG.

DISCUSSION

THE BASIC SECTIONS WERE CHECKED FOR BENDING, AXIAL LOAD, TORSION, AND STABILITY.

A LUG ANALYSIS WAS PERFORMED ON THE BOLTED ATTACH JOINTS AND A PIN BENDING CHECK ON THE BOLTS WAS MADE.

PREPARED BY Westel 5-30-7 CHECKED BY ____ REVISED BY ____

ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE

3.2.6.2

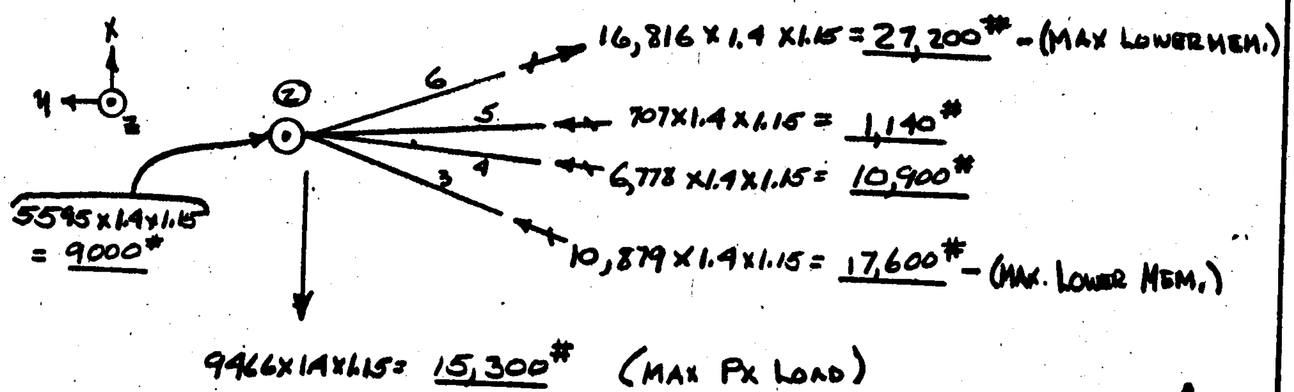
MAXIMUM MEMBER LOADS: (REF 3.2.1)

LIMIT LOAD = MASS x 4.62 G's x 1.5 DYNAMIC FACTOR = 1130 RUN #2 LOADS

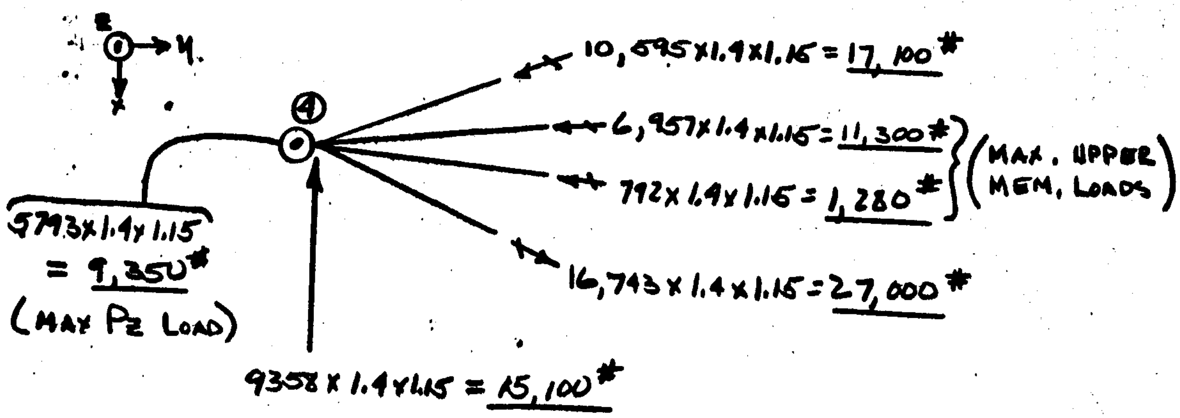
ULT LOAD = LIMIT LOAD x 1.4 ULT FACTOR

FITTING LOAD = ULT. LOAD x 1.15 FITTING FACTOR

NODE POINT ② LOAD CASE #2 ULT FTG. LOAD



NODE POINT ④ LOAD CASE #2 ULT FTG LOAD

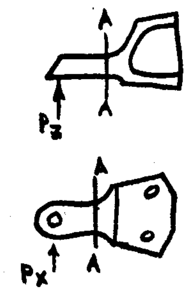
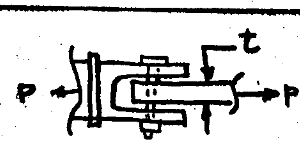
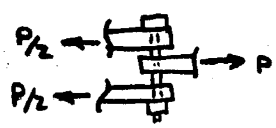
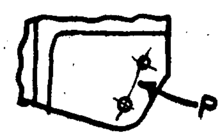
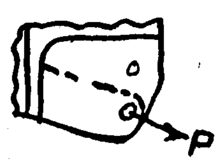
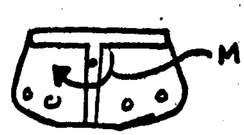
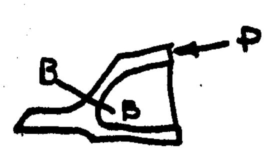


DEN 065098 (3-56)

PREPARED BY Westedt 8-30-67 CHECKED BY ______ REVISED BY ______

ANALYSIS OF AAP/PIP MISSION 1A STRUCTURE

3.2.6-2

STRESS CHECK	SECTION	CRITICAL CONDITION	MARGIN OF SAFETY
BENDING @ SEC A-A		COMPRESSION BENDING	+ LARGE
SIZE THK. OF LOWER FLANGE (t)		t = BEARING CRITICAL = .500	+ .26
PIN BENDING - PH15-7 MO BOLT HT 190 Ksi, F_b = 299 Ksi		BENDING	+.93
LOWER LUG AS A FLANGE		BEAM-COLUMN	+ LARGE
SIZE LOWER FLANGE AS LUG		ULTIMATE SHEAR-BEARING	+.18
T-SECTION FOR TWISTING		TORQUE	+ LARGE
UPPER FLANGE FOR BENDING AT SEC. B-B		BENDING + AXIAL COMPRESSION	+.36

DEN 06500 (3-58)

PREPARED BY WESTEDT 8-30-7 CHECKED BY ______ REVISED BY ______

ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE

3.2.6.3

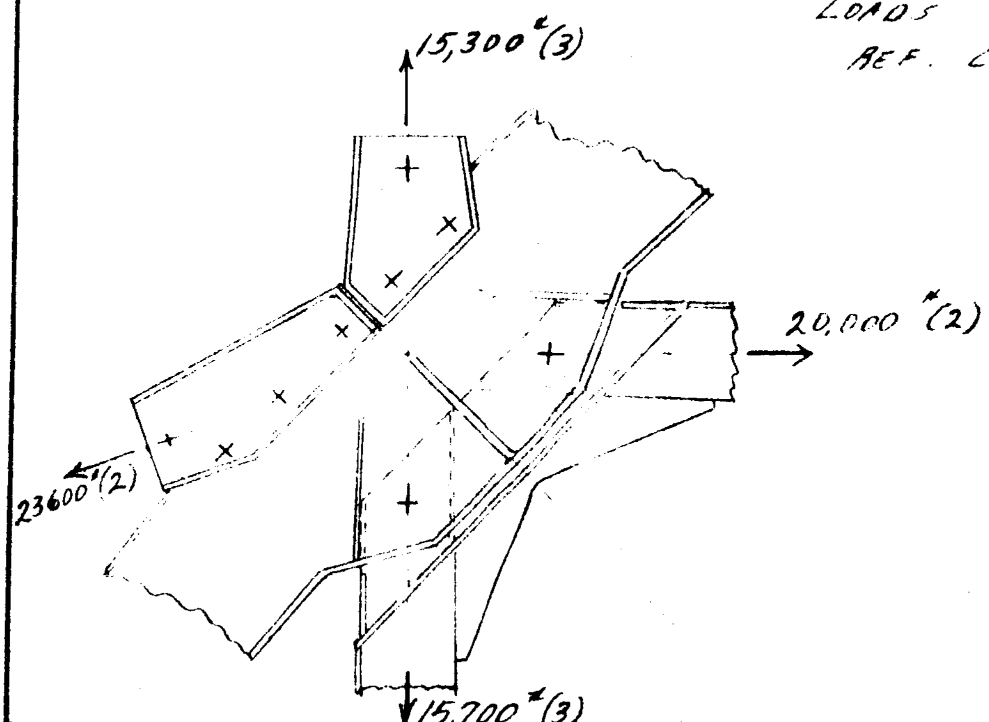
PART DESCRIPTION

FITTING - MAIN SUPPORT TRUSS TO EQUIPMENT TRUSS AT LOWER CORNER OF CONE (NODE PTS 13 TO 16)

CRITICAL CONDITION

COND NO SHOWN IN ( )

LOADS ARE ULTIMATE
REF. COMPUTER RUN #2



DISCUSSION

ABOVE SKETCH SHOWS MAXIMUM LOADS FOR EACH MEMBER AT THE JOINT. THE LOADS AS SHOWN ARE MAX. VALUES ∴ ARE NOT IN EQUILIBRIUM.

THESE FITTINGS WILL HAVE A FITTING FACTOR OF 1.15 APPLIED TO ULT. LOADS. FITTINGS ARE CAPABLE OF WITHSTANDING 10% SIDE LOAD TO ACCOUNT FOR ANY ECCENTRICITIES.

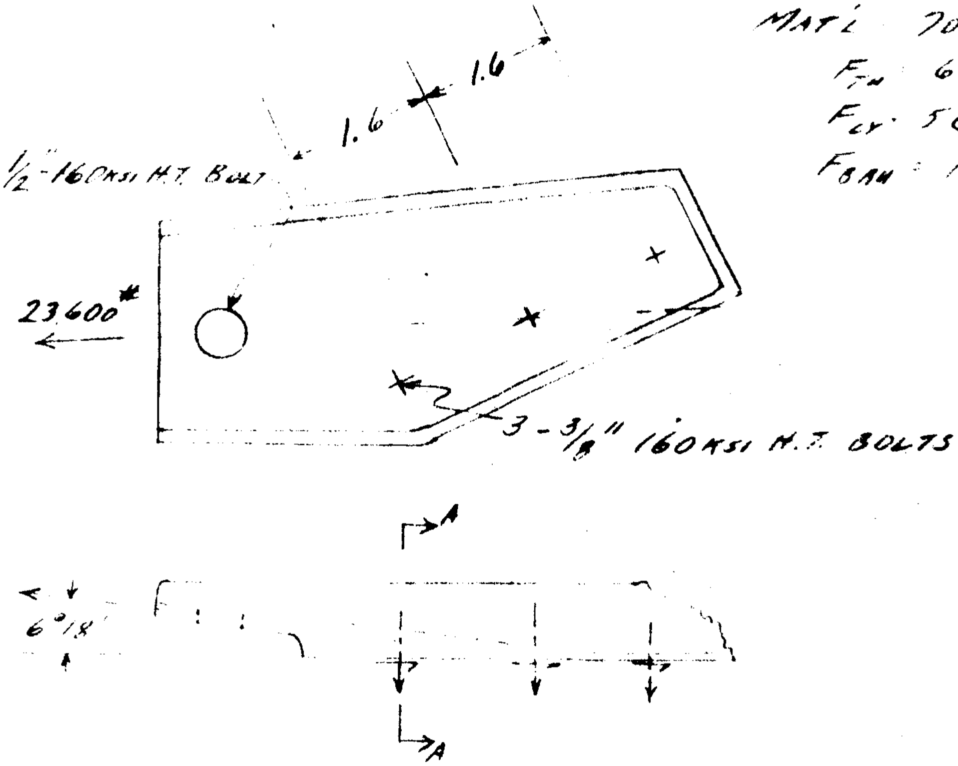
PREPARED BY Hettle Cox 8-28-67 CHECKED BY ________ REVISED BY ________

ANALYSIS OF AAP/PIP MISSION 1A STRUCTURE

3.2.6.3

FITTING - MAIN SUPPORT TRUSS INBD

MAT'L 7075-T73 HAND FORG.
F_{TU} 66 KSI (L)
F_{CY} 56 KSI (L)
F_{BRU} = 119 KSI ($\frac{e}{D}$ = 2.0)



3/8" BOLTS IN SHEAR

$P_{BOLT} = \frac{23600}{3} = 7,870^{\#}$

A FITTING FACTOR OF 1.15 WILL BE USED.

$P_{SU} = 10,490^{\#}$ BOLT F_{SU} = 95,000 psi REF MIL HDBK 5A p. 8.1.2(a)

$M.S. = \frac{10,490}{(7,870)(1.15)} - 1 = .15$

PREPARED BY [signature] 8-28-67 CHECKED BY ____ REVISED BY ____

ANALYSIS OF AAP/PIP MISSION 1A STRUCTURE

3.2.6.3

FITTING - MAIN SUPPORT TRUSS INBD CONT.

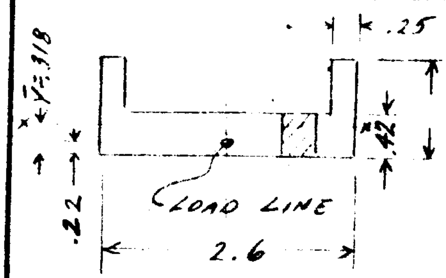
1/2" BOLT IN DOUBLE SHEAR A-286 F_{su} 95 KSI

$P_{su} = (2)(18,650) = 37,300^{\#}$ REF MIL HDBK 5A p 8.1.2.21

$P_{BRU} = A_{BRG} F_{BRU} = (.50)(.50)(119,000) = 29,800^{\#}$

$M.S. = \dfrac{29800}{(23,600)(1.15)} - 1 = .10$

SEC A-A IN TENSION & BENDING



$A = 1.234 \text{ in}^2$

$I_{xx} = .404 \text{ in}^4$

$P_{AXIAL} = 23,600^{\#}$

$Mom = (23,600)(.318 - .220) = 2,310 \text{ in-lb}$

$\text{MAX } f_T = \dfrac{23,600}{1.234} + \dfrac{(2310)(.318)}{.404} = 20,900 \text{ psi}$

$F_{TU} = 66,000 \text{ psi}$

$M.S. = \dfrac{66,000}{(20,900)(1.15)} - 1 = 1.75$

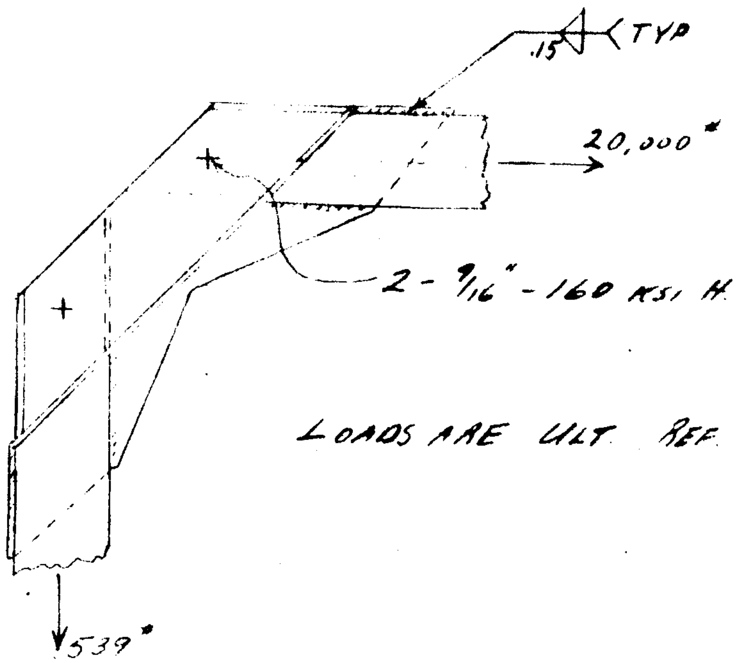
GEN 065033 (3-56)

PREPARED BY Nettleton CHECKED BY __________ REVISED BY __________
8-28-67

**ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE**

3.2.6.3

FITTING - EQUIPMENT TRUSS OUTBD



LOADS ARE ULT. REF. RUN #2

9/16" BOLTS IN SHEAR

MAX $P_{BOLT} = 20,000^{\#}$

ALLOW. $P_{SU} = 23,610^{\#}$ REF MIL HDBK 5A

$$M.S. = \frac{23,610}{(20,000)(1.15)} - 1 = .02$$

PREPARED BY [signature] 8-23-67 CHECKED BY ________ REVISED BY ________

ANALYSIS OF AAP/PIP MISSION 1A STRUCTURE

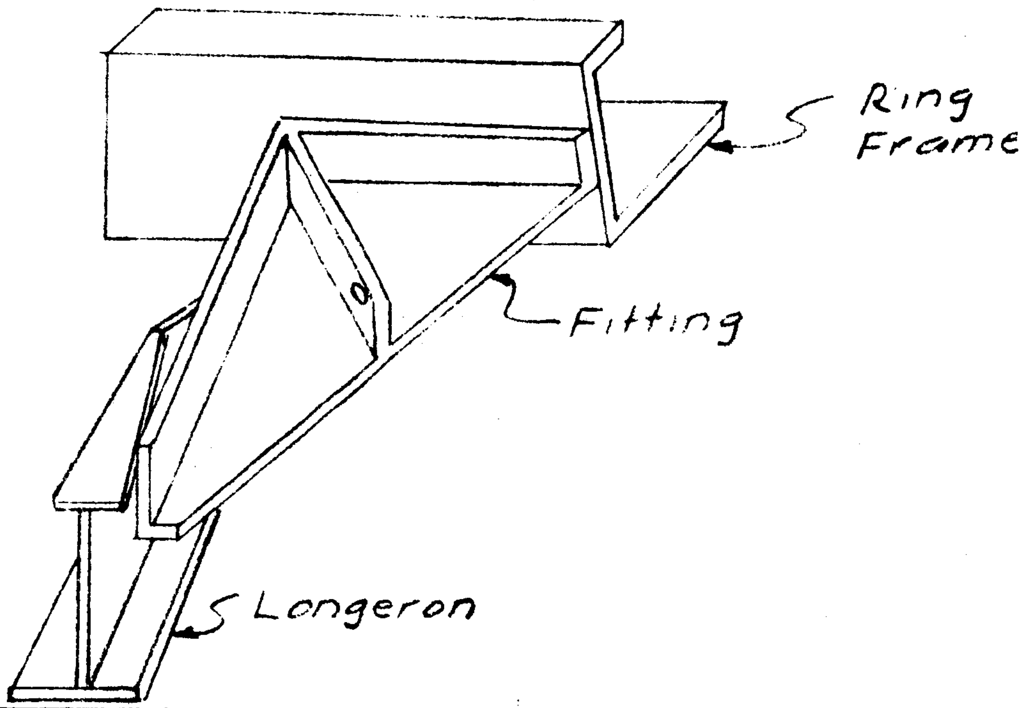
3.2.6.4

PART DESCRIPTION

Upper Truss Member to Pressure Hull Fitting (Node Points 9-12)

CRITICAL CONDITION

Cond No. 2, Member No. 14



DISCUSSION

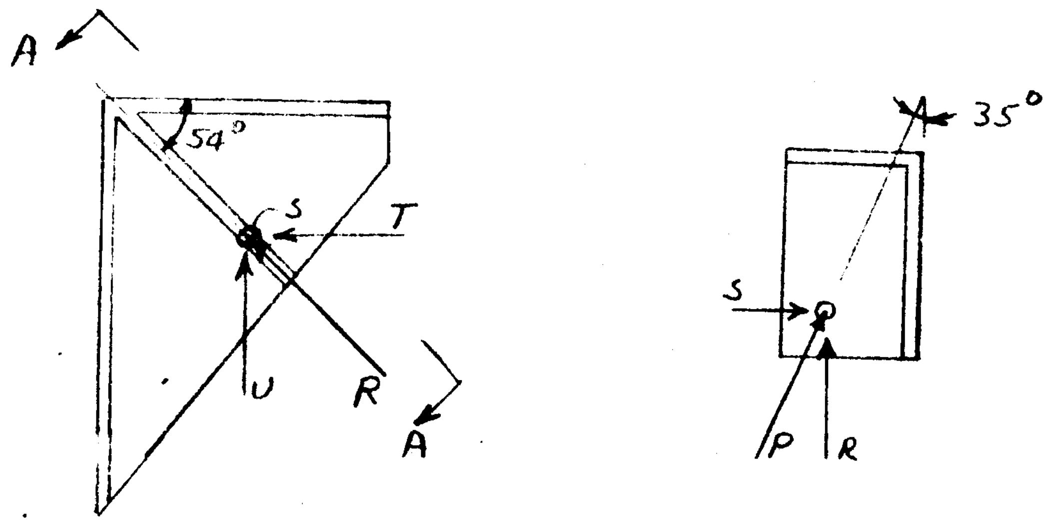
These fittings are used to transfer loads from members 4, 5, 13, 14, 19, 20, 21 & 22 to the longerons and ring frame

PREPARED BY JKT CHECKED BY ______ REVISED BY ______

ANALYSIS OF AAP/PIP MISSION 1A STRUCTURE

3.2 6.4

Upper Truss Member Fitting Cont'd



$P = 9750^{\#}$
$R = 9750 \cos 35° = 8000^{\#}$
$S = 9750 \sin 35° = 5600^{\#}$
$T = 8000 \cos 54° = 4700^{\#}$
$U = 8000 \sin 54° = 6470^{\#}$

Use Fitting Factor of 1.15

$P = 9750(1.15) = 11,200^{\#}$
$R = 8000(1.15) = 9,200$
$S = 5600(1.15) = 6,450$
$T = 4700(1.15) = 5,400$
$U = 6470(1.15) = 7,450$

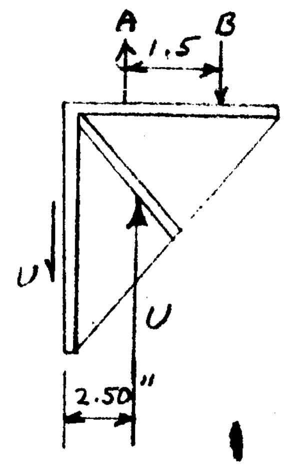
3.2.6.4

Upper Truss Member Fitting Cont'd

Internal Loads Due To Load U

$U = 6470^{\#}$

$A = B = 6470\left(\frac{2.5}{1.5}\right) = 10{,}800^{\#}$

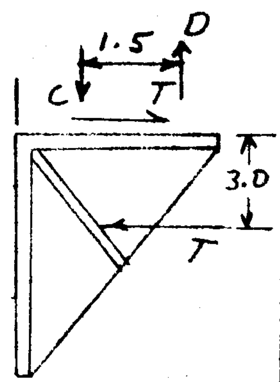


Internal Loads Due To Load T

$T = 4700^{\#}$

$C = D = 4700\left(\frac{3.0}{1.5}\right) = 9400^{\#}$

$B - D = A - C = 1400^{\#}$



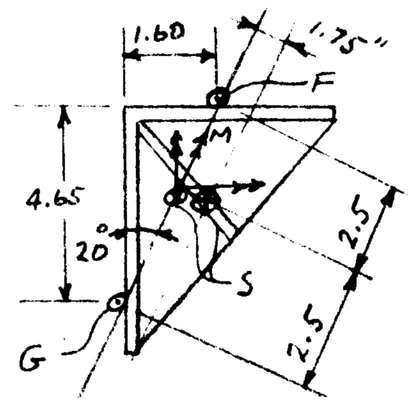
DEN 065038 (3-56)

PREPARED BY JRT CHECKED BY REVISED BY

3.2.6.4

Upper Truss Member Fitting Cont'd

Internal Loads Due To Load S



$S = 5600^{\#}$

$M = 5600(1.75) = 9800''^{\#}$

$M \cos 20^\circ = 9200^{\#}$

$M \sin 20^\circ = 3350^{\#}$

$$F = \tfrac{1}{2}(5600) + \frac{9200}{1.60} - \frac{3350}{4.65}$$
$$= 2800 + 5750 - 720$$
$$= 7830^{\#}$$

$$G = \tfrac{1}{2}(5600) - \frac{9200}{1.60} + \frac{3350}{4.65}$$
$$= 2800 - 5750 + 720$$
$$= -2230^{\#}$$

Combined shear at Ring Frame Bolts

$$\text{Shear} = F \overset{\rightarrow}{+} T$$
$$= 7830 \overset{\rightarrow}{+} 4700$$
$$= 9140^{\#}$$

$\text{Tension} = 1400^{\#}$

Combined Shear at Longeron Bolts

$$\text{Shear} = G \overset{\rightarrow}{+} U$$
$$= 2230 \overset{\rightarrow}{+} 6470$$
$$= 6850^{\#}$$

ANALYSIS OF AAP/PIP MISSION 1A STRUCTURE

3.2.6.4

Upper Truss Member Fitting Cont'd

Check Ring Frame Bolts

Make connection bearing critical

Material 7075 T 73 $F_{br} = 119,000$ psi

Use 2-5/16" dia bolts @ 7290# single shear

Max material thickness $= \frac{7290}{119\,000(.312)} = .195"$

Use Flange thickness = .20" (spotfaced)

$$R_S = \frac{9140}{2(7290)} = .629$$

$$R_T = \frac{1400}{2(8590)} = .082$$

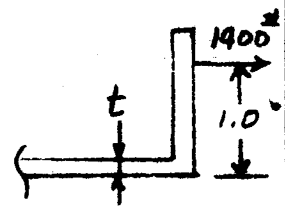
$$M.S. = \frac{1}{\sqrt{(.629)^2 + (.082)^2}} - 1 = \underline{\underline{.58}}$$

Check Fitting Flange at Ring Frame

Effective length = 1.5"

Use $F_{tu} = 66,000$ psi

$$t_{req'd} = \sqrt{\frac{6(1400)(1.0)}{1.5(66,000)}} = .292$$



PREPARED BY JRT CHECKED BY REVISED BY

**ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE**

3.2.6.4
Upper Truss Member Fitting Cont'd

Check Longeron Bolts

Use 3 - 3/16" dia bolts @ 2623# single shear
Load = 6850#.

$$M.S. = \frac{3(2623)}{6850} - 1 = .15$$

PREPARED BY JRT CHECKED BY REVISED BY

3.2.6.5

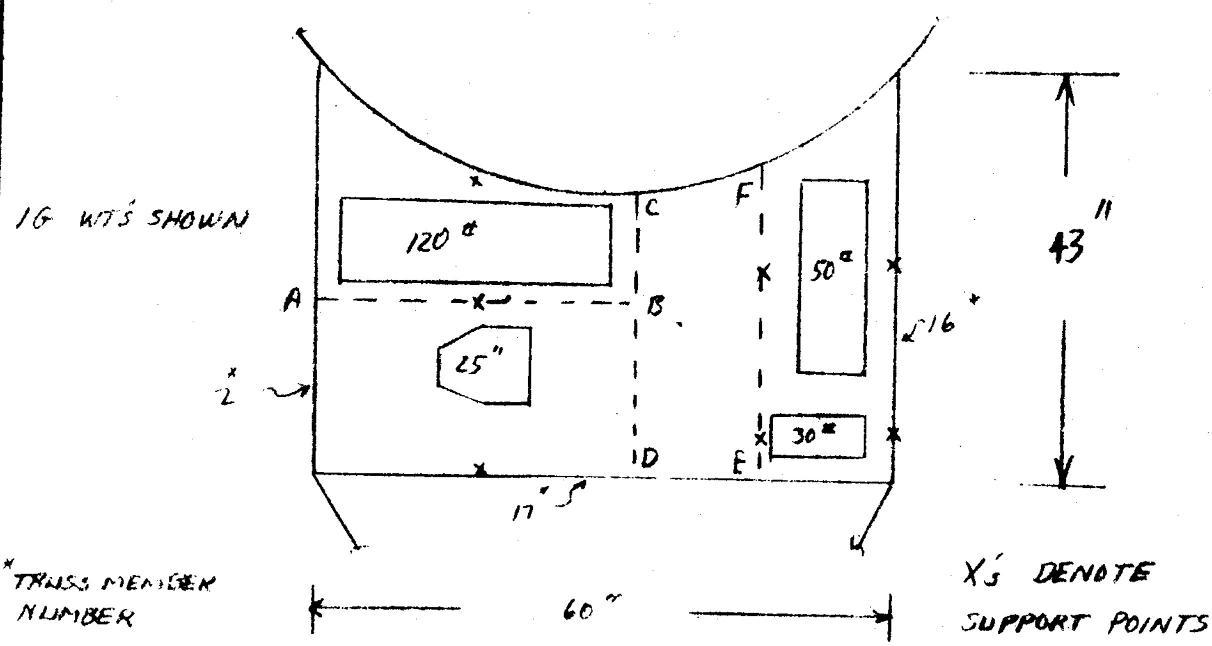
**ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE**

PART DESCRIPTION

LOWER PANEL, LEFT EXPERIMENT CAVITY

CRITICAL CONDITION CONDITION (1)

6.92 g's AFT (LIMIT LOAD)



DISCUSSION

THE PANEL IS SKIN STIFFENED BY MEMBERS INDICATED BY THE DOTTED LINES IN THE ABOVE SKETCH. EXPERIMENT LOADS WILL BE APPLIED TO THE STIFFENERS & THE ADJACENT PRESSURE HULL FRAME + THE PRIMARY SUPPORT MEMBERS AT THE LOCATIONS DENOTED BY X.

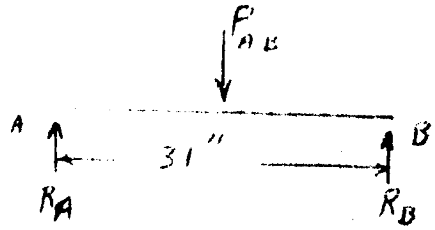
PREPARED BY gn CHECKED BY ________ REVISED BY ________

ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE

3.2.6.5

MEMBER A-B

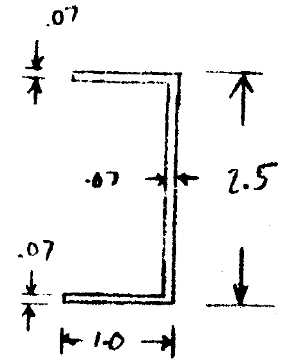
$P_{A-B} = (1.92)(1.4)\left[\frac{170}{2} + \frac{25}{2}\right] = 703^{\#}_{ULT}$



$M_{MAX} = \frac{703(155)}{2} = 5450^{"\#}$ ULT

$I = 2\left[.07(1.215)^2\right] + \frac{.07(2.36)^3}{12} = .284\ in^4$

$\sigma_{M} = \frac{5450(1.215)}{.284} = 23300$ psi ult



2219-T87

CHECK COMPRESSION FLANGE

$\frac{b}{t} = \frac{1}{.07} = 14.3$

$f_{cc} = 27500$ psi

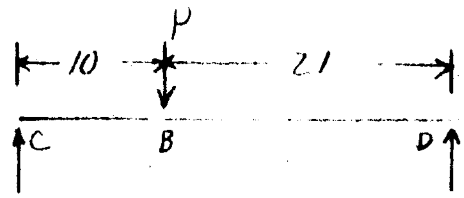
$MS = \frac{275}{233} - 1 = .18$

PREPARED BY ____ CHECKED BY ____ REVISED BY ____

ANALYSIS OF AAP/PIP MISSION 1A STRUCTURE

3.2.6.5

MEMBER C-B-D

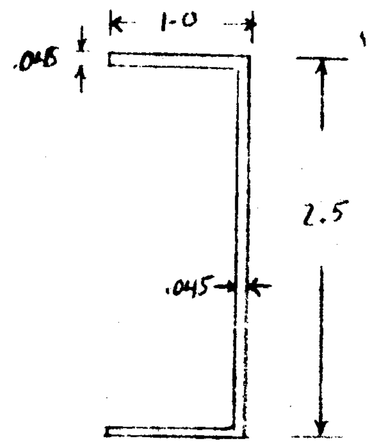


$P: R_B = \frac{703}{2} = 351^{\#}$ ULT

$R_C = \frac{21}{31}(351) = 238^{\#}$ ULT

$R_D = \frac{10}{31}(351) = 113^{\#}$ ULT

$M_{MAX} = 10R_C = 2380^{''\#}$ ULT



$I = 2\left[.045(1.2275)^2\right] + \frac{.045(2.41)^3}{12} = .1887 \text{ in}^4$

$\sigma = \frac{2380(1.2275)}{.1887} = 16100$ psi ULT

CHECK COMPRESSION FLANGE

$\frac{b}{t} = \frac{1}{.045} = 21.2$

$f_{cc} = 19500$ (REF FIG)

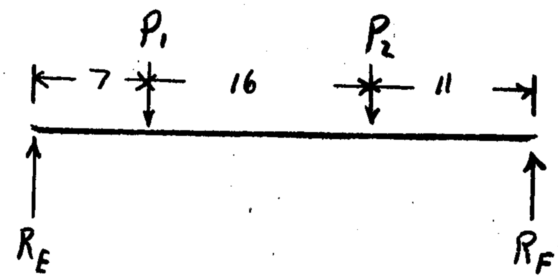
$MS = \frac{19500}{16100} - 1 = .21$

PREPARED BY [signature] CHECKED BY REVISED BY

ANALYSIS OF AAP/PIP MISSION 1A STRUCTURE

3.2.6.5

MEMBER F-E.



$P_1 = \frac{1}{2}[4.62(1.4)(1.5)30]$

$= 146^{\#}$ ULT

$P_2 = \frac{1}{2}[4.62(1.4)(1.5)50] = 243^{\#}$ ULT

$R_E = \frac{27}{34}(146) + \frac{11}{34}(243) = 195^{\#}$ ULT

$R_F = 194^{\#}$ ULT

$M_1 = 195(7) = 1365$ "# ULT

$M_2 = 194(11) = 2135$ "# ULT

USE THE SAME SECTION AS MEMBER C&D

$I = .1887$
$C = 1.2275$

$\sigma = \frac{2135(1.2275)}{.1887} = 13900$ psi ULT

$f_{cc} = 19500$

$MS = \frac{19500}{13900} - 1 = .40$

DEN 065098 (3-58)

PREPARED BY gm CHECKED BY REVISED BY

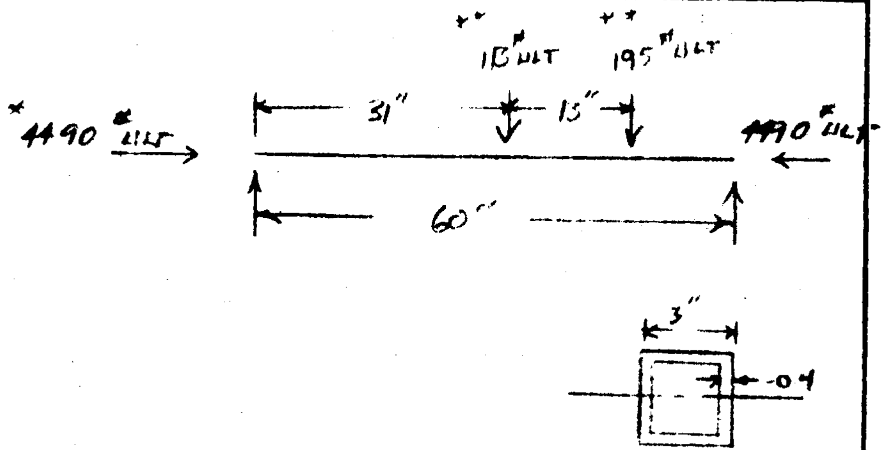
ANALYSIS OF AAP/PIP MISSION 1A STRUCTURE

3.2.6.6

PART DESCRIPTION PRIMARY TRUSS MEMBER #17***

CRITICAL CONDITION LOAD CASE 1

6.92 g's AFT



* REF TABLES

** REF 3.2.6.5

*** REF FIG 2

MAT'L : 2219-T87

AREA = .493 IN^2

I = .694 IN^4

DISCUSSION

THE MEMBER MUST BE CHECKED AS A BEAM-COLUMN SINCE LATERAL LOADS DUE TO LOCAL EQUIPMENT SUPPORT ARE EXPERIENCED AS WELL AS AXIAL LOADS TAKEN AS PART OF PRIMARY STRUCTURE. ANALYSIS WILL BE DONE BY MACHINE PROGRAM.

PREPARED BY ______ CHECKED BY ______ REVISED BY ______

ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE

3.2.6.6

RESULTS OF COMPUTER ANALYSIS

MAX DEFLECTION	.202 " ULT
MAX STRESS	18202 psi ULT
Fcc	18300 psi
MARGIN OF SAFETY (STRESS)	0.006

THE ITERATION CONVERGES AFTER 5 CYCLES.
THE BEAM-COLUMN IS NOT STABILITY CRITICAL

GEN 065048 (3-56)

PREPARED BY ___ CHECKED BY ___ REVISED BY ___

ANALYSIS OF AAP/PIP MISSION 1A STRUCTURE

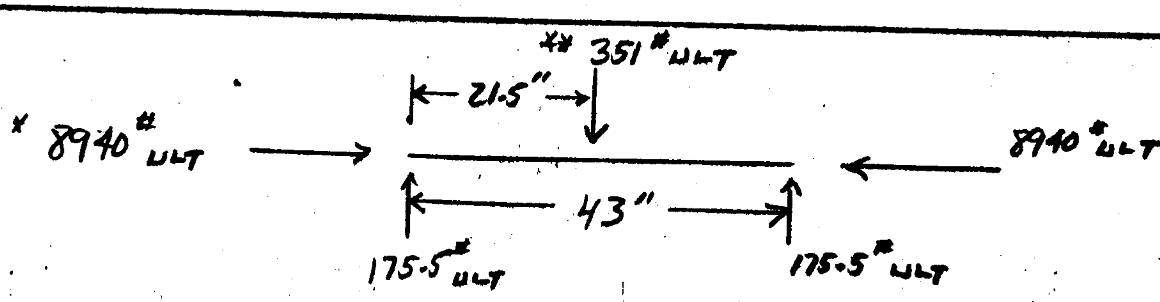
3.2.6.7

PART DESCRIPTION

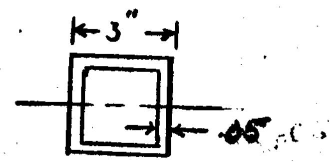
PRIMARY TRUSS MEMBER #2 ***

CRITICAL CONDITION

CASE (3) ~ 4.5g's Z (AFT) + 3.75g's Y



* REF TABLE 5
** REF 3-2.6.5
*** REF FIG 2.6



2219-T87
AREA = .59 in^2
$I = 0.858 \ in^4$
$f_{cc} = 23000$ psi

(col) $\frac{L}{r}$ eq 15.5

DISCUSSION

THIS MEMBER MUST BE CHECKED AS A BEAM-COLUMN SINCE LATERAL LOADS DUE TO LOCAL EQUIPMENT SUPPORT ARE EXPERIENCED AS WELL AS AXIAL LOADS TAKEN AS PART OF PRIMARY STRUCTURE. ANALYSIS WILL BE DONE BY MACHINE PROGRAM.

PREPARED BY JM CHECKED BY _____ REVISED BY _____

ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE

3.2.6.7

RESULTS OF COMPUTER ANALYSIS

MAX DEFLECTION .078" ult

MAX STRESS 22660 psi
F_c 22700 psi
MARGIN OF SAFETY (STRESS) 0

THE ITERATION CONVERGES AFTER 5 CYCLES.

THE BEAM COLUMN IS NOT STABILITY CRITICAL.

PREPARED BY ______ CHECKED BY ______ REVISED BY ______

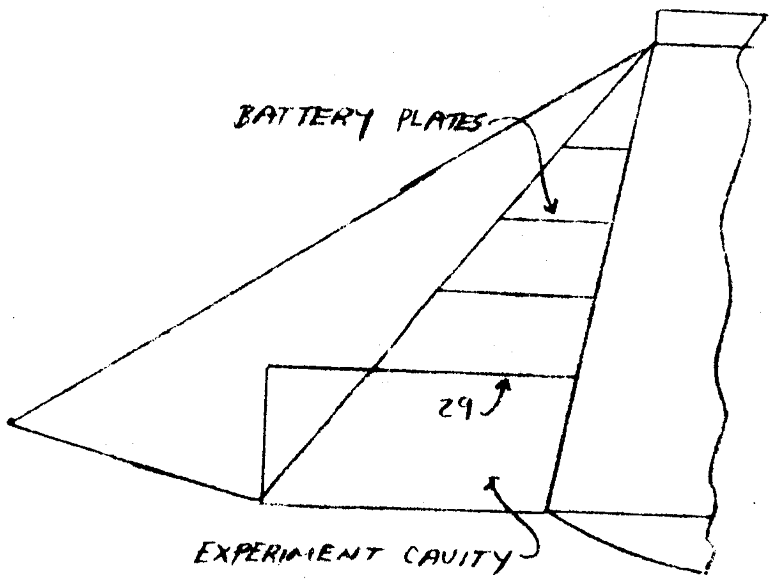
ANALYSIS OF AAP/PIP MISSION 1A STRUCTURE

3.2.6.8

PART DESCRIPTION BATTERY MOUNTING PLATE SUPPORT BEAM (MEMBER 29 OF BATTERY SUPPORT STRUCTURE MODEL)

CRITICAL CONDITION

CASE 2 - 4.5 g's AFT(Z), 3.75 g's LATERAL (X) LIMIT



DISCUSSION THE BATTERY MOUNTING PLATES WILL BE SUPPORTED MAINLY BY THE BEAMS IN THE TRIANGULAR SIDES OF THE BATTERY SUPPORT STRUCTURE. FUNCTIONING AS MEMBERS OF THE COMPLETE BATTERY SUPPORT STRUCTURE, THE INDIVIDUAL BEAMS CARRY AXIAL LOAD. IN THE CRITICAL CASE NOTED ABOVE, THE AXIAL LOAD IS COMPRESSIVE. FOR THE BEAM-COLUMN CHECK THE LOAD DUE TO BATTERIES, ETC WILL BE ASSUMED TO BE CARRIED UNIFORMLY BY THE SUPPORT BEAMS. THE PROBLEM WILL BE SOLVED BY MACHINE PROGRAM.

PREPARED BY ____ CHECKED BY ____ REVISED BY ____

**ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE**

3.2.6.8

MEMBER 29 (CON'T)

TOTAL PANEL WT

EXPERIMENT SUBSYSTEMS	83#
BATTERIES	350#
	433# (1G)

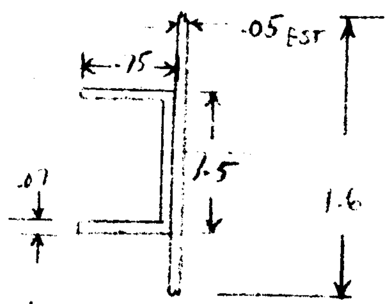
LOAD APPLIED TO BEAM (NORMAL)

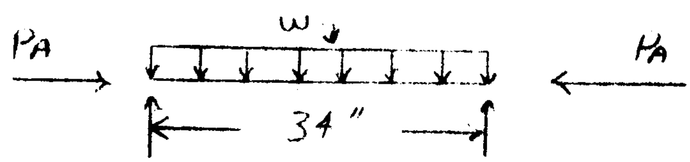
$$^{*}\omega = \frac{1}{2}\left[\frac{\frac{1}{2}(433)}{33.8}(1.4)(4.5)\right] = 20\,\#/'' \text{ ULT (NET)}$$

*(IT IS ASSUMED THAT $\frac{1}{2}$ THE NORMAL LOAD IS CARRIED BY TENS. IN THE SKIN PANELS)

AXIAL LOAD

P_A = 580# ULT (REF COMPUTER RUN SECT. 3.2.3)





MAT'L: 2219-T87
AREA: .290 in^2
I = .0931 in^4

FROM COMPUTER RUN:
MAX. STRESS = 26970 psi ULT
MAX. DEFLECTION = .379"
M.S. = .315
CONVERGENCE AFTER 3 ITERATIONS

PREPARED BY JN ____ CHECKED BY ____ REVISED BY ____

ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE

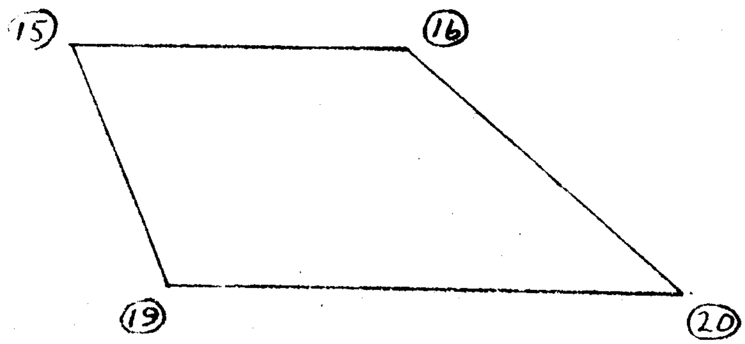
3.2.6.9

PART DESCRIPTION

Side Shear Panel
Battery Support Structure

CRITICAL CONDITION

Case 2 - $N_x = 3.75$, $N_y = 0$, $N_z = 4.5$ (Limit)



DISCUSSION

This shear panel was idealized into equivalent axial members (No. 39 & 40 or 30 & 31) for the battery support structure computer program. The calculated loads in these members will now be transformed into shears and the panel will be analyzed as shear resistant.

PREPARED BY JRT CHECKED BY REVISED BY

**ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE**

3.2.6.4

Side Shear Panel Cont'd

$\theta = \tan^{-1} \frac{25.4}{29.3} = 40°55'$

$\beta = \tan^{-1} \frac{25.4}{49.8} = 27°05'$

$A = 2080 \cos\theta = 1572^{\#}$

$B = 2080 \sin\theta = 1362$

$C = 720 \cos\beta = 640$

$D = 720 \sin\beta = 328$

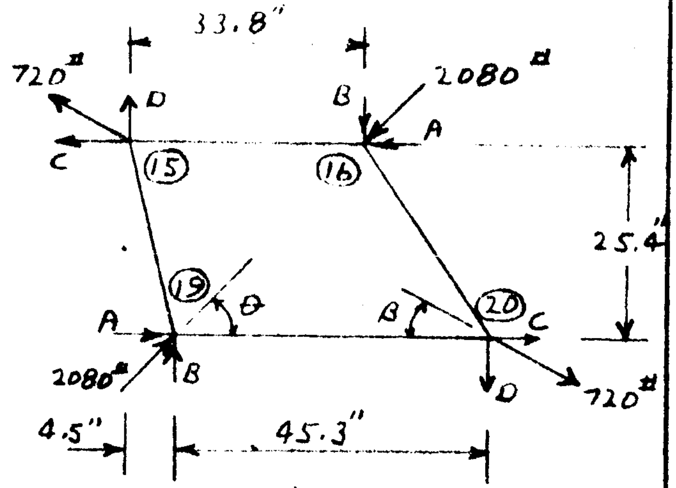
$A + C = 2212^{\#}$

$B + D = 1690^{\#}$

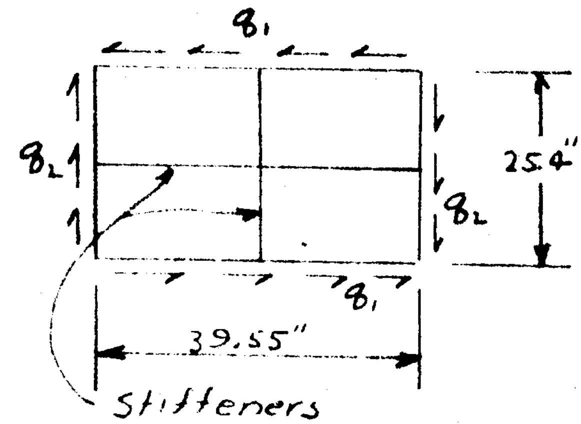
$q_1 = \frac{2212}{39.55} = 54.0 \ ^{\#}/_{in}$

$q_2 = \frac{1690}{25.4} = 66.6 \ ^{\#}/_{in}$

USE AVERAGE $q = 60.3 \ ^{\#}/_{in}$



ACTUAL PANEL



EQUIVALENT

Check Shear stress
Panel thickness = .06"

$f_s = \frac{60.3}{.06} = 1005$ psi

Check buckling stress:
See Roark, Table XVI,
Case D

$F_s = K \frac{E}{1-\mu^2} \left(\frac{t}{b}\right)^2$

$a/b = 39.55/25.4 = 1.55 \qquad K = 5.80$

$F_s = 5.80 \frac{10.5 \times 10^6}{1-(.33)^2} \left(\frac{.06}{12.7}\right)^2 = 1510$ psi

$M.S. = \frac{1510}{1005} - 1 = \underline{\underline{.50}}$

PREPARED BY JRT CHECKED BY ______ REVISED BY ______

**ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE**

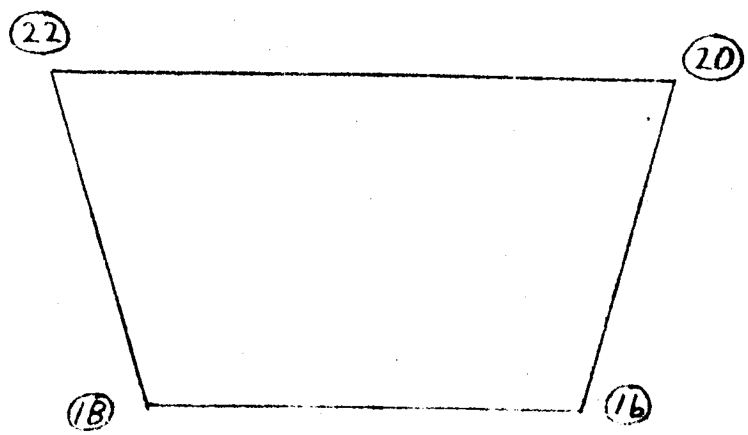
3.2.6.9

PART DESCRIPTION

Lower Shear Panel
Battery Support Structure

CRITICAL CONDITION

Case 3 - $N_x = 0$, $N_y = 3.75$, $N_z = 4.5$ (Limit)



DISCUSSION

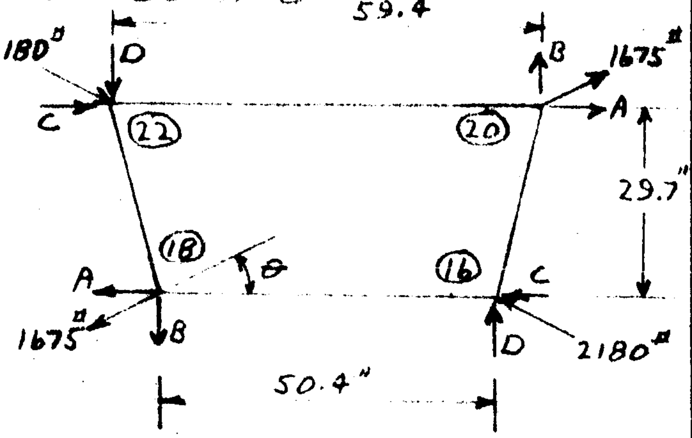
This shear panel was idealized into equivalent axial members (No. 48 & 49) for the battery support structure computer program. The calculated loads in these members will now be transformed into shears and the panel will be analyzed as shear resistant.

PREPARED BY JRT CHECKED BY REVISED BY

ANALYSIS OF AAP/PIP MISSION 1A STRUCTURE

3-26-9

Lower Shear Panel Cont'd



ACTUAL PANEL

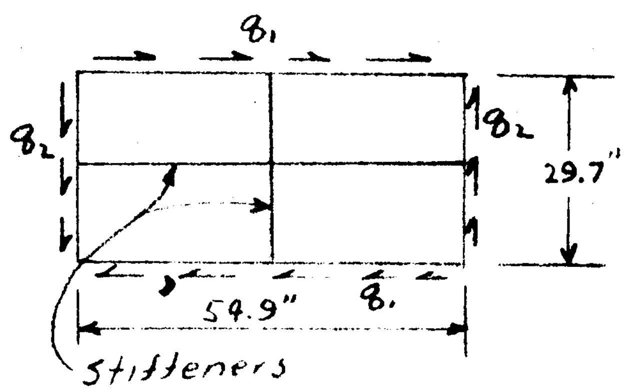
$\theta = \tan^{-1} \frac{29.7}{54.9} = 28°25'$

$A = 1675 \cos\theta = 1472^{\#}$
$B = 1675 \sin\theta = 796^{\#}$
$C = 2180 \cos\theta = 1918^{\#}$
$D = 2180 \sin\theta = 1039^{\#}$

$A + C = 3390^{\#}$
$B + D = 1835^{\#}$

$q_1 = \frac{3390}{54.9} = 61.9\ ^{\#}/_{"}$

$q_2 = \frac{1835}{29.7} = 61.9\ ^{\#}/_{"}$ (check)



EQUIVALENT PANEL

Check shear stress:
Panel thickness = .06"
$f_s = \frac{61.9}{.06} = 1030$ psi

Check buckling stress:
See Roark, Table XVI, Case D
$F_s = K \frac{E}{1-\mu^2} \left(\frac{t}{b}\right)^2$
$a/b = 27.45/14.85 = 1.85$ $K = 5.55$

$F_s = 5.55 \frac{10.5 \times 10^6}{1-(.33)^2} \left(\frac{.06}{14.85}\right)^2 = 1060$ psi

$M.S. = \frac{1060}{1030} - 1 = \underline{\underline{.03}}$

PREPARED BY JRT CHECKED BY ____ REVISED BY ____

ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE

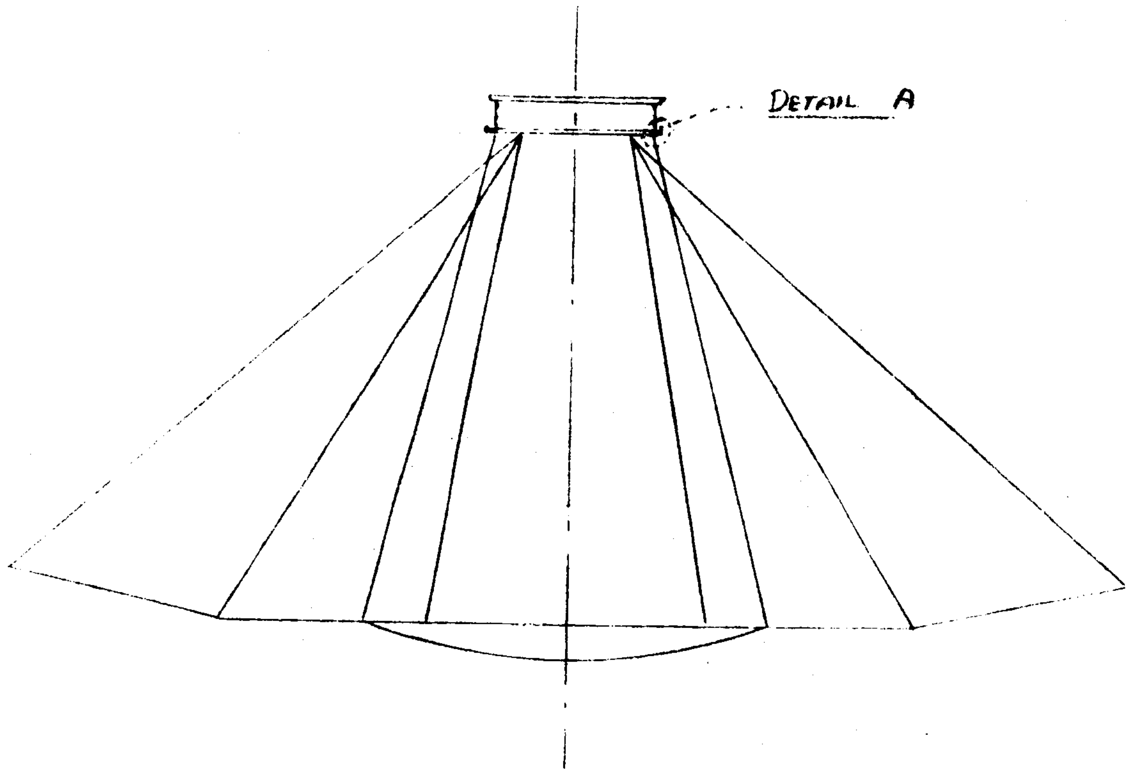
3.2.6.10

PART DESCRIPTION

CONE - DOCKING COLLAR RING FRAME

CRITICAL CONDITION

COND NO. 2, MEMBER # 35-42, NODE PT. 20, REF APP #2



DISCUSSION

BOTTOM OF DOCKING COLLAR ACTS AS A STABILIZATION RING FRAME TAKING COMPRESSIVE LOADS FROM THE MAIN SUPPORT TRUSS. THE RING FRAME WILL BE CHECKED FOR MAX. STRESS USING THE INTERNAL FORCES COMPUTED BY MACHINE. STABILITY WILL BE CHECKED USING A RING UNDER A UNIFORM RADIAL LOAD WHICH PRODUCES THE SAME MAX. COMPRESSIVE STRESS.

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ANALYSIS OF AAP/PIP MISSION 1A STRUCTURE

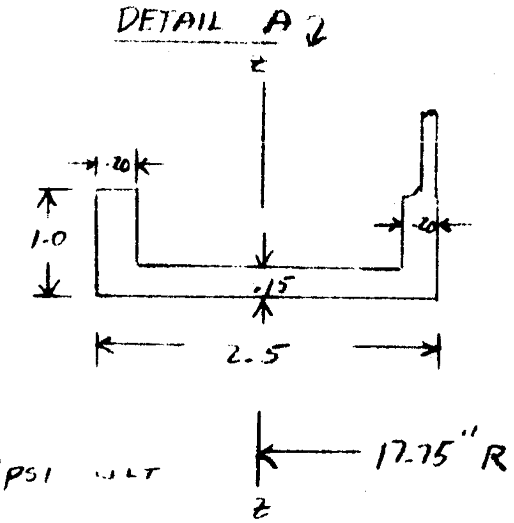
3-2-6-10

LOADS

$P_A = 3290^{\#}_{LL} = 4600^{\#}\ ULT$

$M = 10023^{''\#}_{LL} = 14030^{''\#}\ ULT$

DETAIL A



$$I = 2\left[1(.20)(1.15)^2\right] + \frac{.15(2.1)^3}{12} = .644\ in^4$$

$$A = 2\left[1(.20)\right] + .15(2.1) = .715\ in^2$$

$$f_{c_{MAX}} = \frac{4600}{.715} + \frac{14030(1.25)}{.644} = 33630\ psi\ ULT$$

$$P_{A\ EQUIV.} = Af_c = .715(33630) = 24100^{\#}\ ULT$$

$$q_{EQUIV.} = \frac{P_{A\ EQUIV.}}{R} = \frac{24100}{17.75} = 1355\ ^{\#}/_{''}\ ULT$$

$$q_{CRITICAL} = \frac{KEI}{R^3} = \frac{3\left[10.5(10^6)\right](.715)}{(17.75)^3} = 4020\ ^{\#}/_{''}$$

$$MS_{STRESS} = \frac{50000}{33630} - 1 = \text{large}$$

$$MS_{STABILITY} = \frac{4020}{1355} - 1 = \text{LARGE}$$

ANALYSIS OF AAP/PIP MISSION 1A STRUCTURE

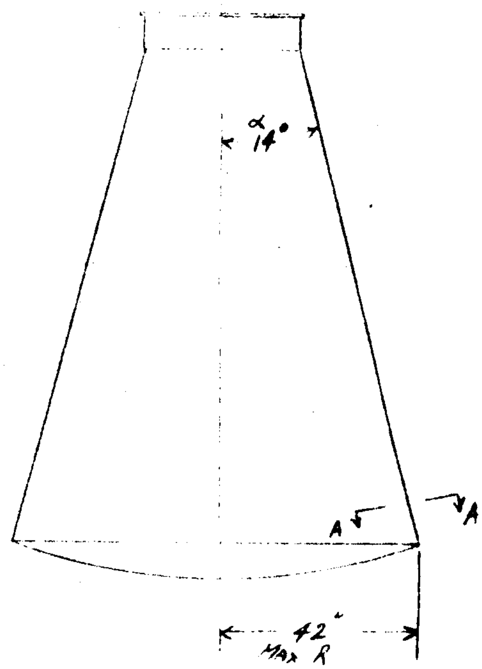
3.2.6.11

PART DESCRIPTION

CONE - PRESSURE VESSLE

CRITICAL CONDITION

INTERNAL PRESSURE - PROOF PRESSURE = 9.5 psig
ULT. PRESSURE = 12.9 psig



DISCUSSION

WELDED .040 SKIN IS SHOWN NOT TO YIELD AT PROOF PRESSURE

ULTIMATE PRESSURE DOES NOT GIVE CRITICAL STRESSES

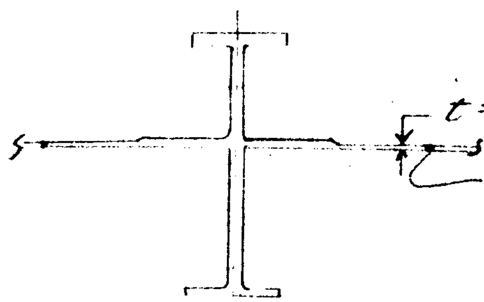
PREPARED BY [signature] CHECKED BY __________ REVISED BY __________
8-30-67

DEN 065098 (3-56)

**ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE**

3.2.6.11

SEC A-A FOR HOOP TENSION



MAT'L 2219 - T87
AS WELDED
F_{TU} = 28,000 psi } REF. FIG 5.6-9
F_{TY} = 12,000 psi } MISSION 1A PROGR. TECH. REQ. & CRITERIA

$$f_{T_{HOOP}} = \frac{pR}{t \cos \alpha}$$

$$f_{T_{HOOP}\,(PROOF)} = \frac{(9.5)(42)}{(.040)(\cos 14^\circ)} = 10,300 \text{ psi}$$

$$\underline{M.S.} = \frac{12,000}{10,300} - 1 = \underline{.16}$$

PREPARED BY [signature] 8-30-67 CHECKED BY ______ REVISED BY ______

ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE

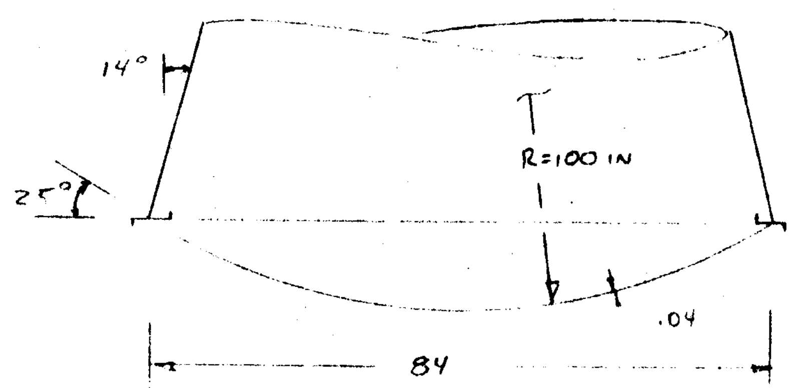
3.2.6.12

PART DESCRIPTION

SPHERICAL CAP & RING FRAME

CRITICAL CONDITION

CASE NO. 4 - ULT PRESSURE = 12.9 PSIG.



DISCUSSION

THE SPHERICAL CAP IS CRITICAL FOR MEMBRANE STRESS.

THE RING FRAME IS CRITICAL FOR RING BUCKLING DUE TO PRESSURE VESSEL KICK LOADS.

ALL MATERIAL ~ 2219-T87

PREPARED BY RC? 8/30/67 CHECKED BY ______ REVISED BY ______

**ANALYSIS
OF
AAP/PIP MISSION 1A STRUCTURE**

3.2.6.12

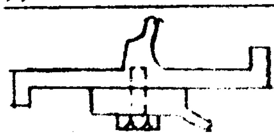
SPHERICAL CAP

MAT'L 2219-T87 $\qquad F_{tu} = 60,000$ PSI

$$f_t = \frac{pR}{2t} = \frac{(12.9)(100)}{2(.04)} = 16,100 \text{ PSI}$$

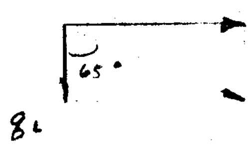
$$M.S. = \frac{60,000}{16,100} - 1 = \text{LARGE}$$

RING FRAME



$(I = 1.29 \text{ IN}^4,\ A = 1.73 \text{ IN}^2)$

$$q_R = \frac{pR}{2}\tan\theta = \frac{(12.9)(42)}{2}\tan 14^\circ = 68 \text{ LBS/IN}$$



$$q_R = \frac{(12.9)(42)}{2}(\tan 65^\circ) = 580 \text{ LBS/IN}$$

TOTAL RADIAL KICK LOAD = 648 LBS/IN

$$q_{CR} = \frac{KEI}{R^3}, \quad PR = 648(42) = 27200^{\#}$$

$$\sigma_A = 15700 \text{ psi}$$

ASSUME THE PRIMARY TRUSS STRUCTURE WILL FORCE 4 BUCKLES; $K = N^2 - 1 = 4^2 - 1 = 15$

$$q_{CR} = \frac{15(10.5\times10^6)(1.29)}{(42)^3} = 2750 \text{ LBS/IN}$$

$$M.S. = \frac{2750}{648} - 1 = \text{LARGE}$$

DEN 065098 (3-56)

PREPARED BY______ CHECKED BY______ REVISED BY______

4.0 CONCLUSION

This analysis has shown that the carrier structure as presently configured is suitable for AAP/PIP Mission 1A purposes and provides a sound basis for further analysis and development to optimize the design with respect to weight and function.

J
Rd

PR 29-26

STUDY REPORT

FLIGHT ARTICLE AND GSE ACCEPTANCE

AAP/PIP EARLY APPLICATIONS

Contract NAS-8-21004

7 September 1967

Prepared by: Paul Hixenbaugh
Paul Hixenbaugh

Approved by: D E Callahan
D. E. Callahan

Martin Marietta Corporation
Denver Division

TABLE OF CONTENTS

FIGURES

1. INTRODUCTION

1.1 Purpose

This study report provides an identification and delineation of the sequence of operations whereby the carrier structure, components, subsystems, and experiments will undergo systematic acceptance and compliance testing during the process of assembly and integration into the 1A carrier. Acceptance testing will be delineated at the integrated carrier system level to provide assurance of a fully qualified flight article.

This study provides identification of an operations sequence whereby the Ground Support Equipment (GSE) will be tested, installed, and demonstrated (where required) for acceptance.

1.2 Objectives

The objectives of this study were as follows:

a. Provide a sequence of operations at Denver to integrate the carrier structure, components-subsystems and the experiments for a baseline upon which to schedule activities, equipment and manpower.

b. Provide a sequence of operations having a minimum cost and schedule impact.

c. Establish an early high confidence level and a continuation through a building block, system by system, approach of assurance testing.

d. Provide maximum practical utilization of existing (or soon to be existing) Denver facilities and supporting operations.

e. Identify areas which may affect cost, schedules or cause delay and will require further study. Where practical provide alternate recommendations for additional investigation.

2. SUMMARY

The results of this study are summarized in the two block flow sequences shown in Figures 2-1 and 2-2.

The sequence of operation commences in the Payload Integrator's facility at Denver with the initial acceptance tests of the carrier structure, components and subsystems, and the receiving of experiments for compliance testing. The sequence of operations continues through the required sequences of carrier buildup and test through to the transport of the various items to KSC.

A block flow sequence is provided in Figure 2-1 wherein it is assumed that all experiments will be integrated in the carrier at Denver.

An alternate block flow sequence is provided in Figure 2-2 wherein it is assumed several experiments will arrive late and will require compliance testing and integration with the carrier at KSC.

3. DENVER GROUND OPERATIONS

Denver ground operations are those operations which must be performed to assemble, service, test and integrate the carrier and experiments to provide a high assurance level that the 1A carrier is ready for flight.

3.1 Requirements and Considerations

The following requirements and considerations and the previously stated objectives provide the parameters of this study.

3.1.1 Carrier Structure Compliance Testing

The carrier structure, after fabrication, will require structural load testing to provide assurance that the carrier structure is capable of withstanding g-loads which will be imposed on the fully assembled carrier during handling, transport by road and air, launch, docking and orbital maneuvering. The carrier structure tests will require the use of simulated equipment loads.

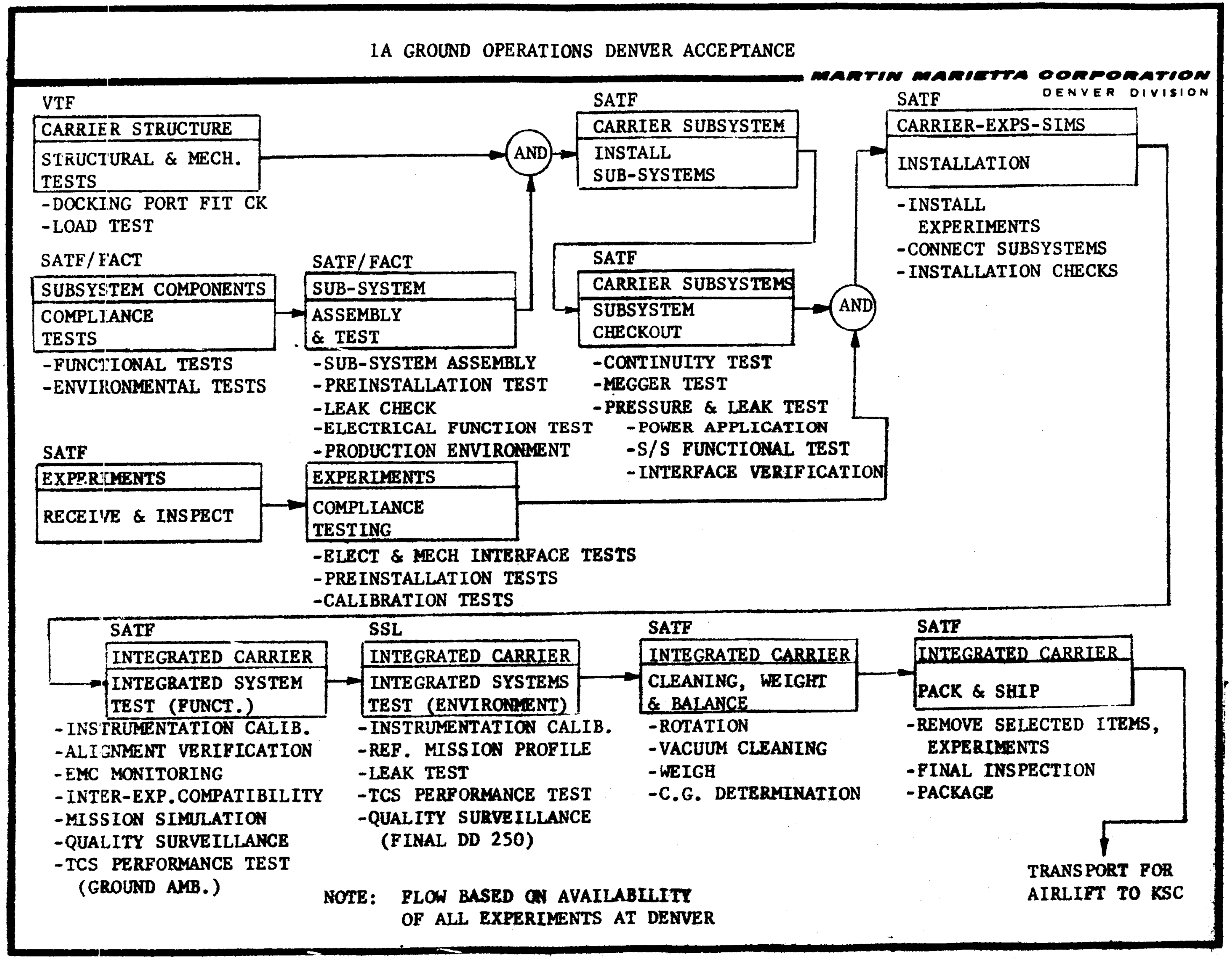

1A GROUND OPERATIONS DENVER ACCEPTANCE
MARTIN MARIETTA CORPORATION
DENVER DIVISION
VTF
CARRIER STRUCTURE
STRUCTURAL & MECH. TESTS
-DOCKING PORT FIT CK
-LOAD TEST
SATF/FACT
SUBSYSTEM COMPONENTS
COMPLIANCE TESTS
-FUNCTIONAL TESTS
-ENVIRONMENTAL TESTS
SATF/FACT
SUB-SYSTEM
ASSEMBLY & TEST
-SUB-SYSTEM ASSEMBLY
-PREINSTALLATION TEST
-LEAK CHECK
-ELECTRICAL FUNCTION TEST
-PRODUCTION ENVIRONMENT
AND
SATF
CARRIER SUBSYSTEM
INSTALL SUB-SYSTEMS
SATF
CARRIER SUBSYSTEMS
SUBSYSTEM CHECKOUT
-CONTINUITY TEST
-MEGGER TEST
-PRESSURE & LEAK TEST
-POWER APPLICATION
-S/S FUNCTIONAL TEST
-INTERFACE VERIFICATION
AND
SATF
CARRIER-EXPS-SIMS
INSTALLATION
-INSTALL EXPERIMENTS
-CONNECT SUBSYSTEMS
-INSTALLATION CHECKS
SATF
EXPERIMENTS
RECEIVE & INSPECT
EXPERIMENTS
COMPLIANCE TESTING
-ELECT & MECH INTERFACE TESTS
-PREINSTALLATION TESTS
-CALIBRATION TESTS
SATF
INTEGRATED CARRIER
INTEGRATED SYSTEM TEST (FUNCT.)
-INSTRUMENTATION CALIB.
-ALIGNMENT VERIFICATION
-EMC MONITORING
-INTER-EXP.COMPATIBILITY
-MISSION SIMULATION
-QUALITY SURVEILLANCE
-TCS PERFORMANCE TEST (GROUND AMB.)
SSL
INTEGRATED CARRIER
INTEGRATED SYSTEMS TEST (ENVIRONMENT)
-INSTRUMENTATION CALIB.
-REF. MISSION PROFILE
-LEAK TEST
-TCS PERFORMANCE TEST
-QUALITY SURVEILLANCE (FINAL DD 250)
SATF
INTEGRATED CARRIER
CLEANING, WEIGHT & BALANCE
-ROTATION
-VACUUM CLEANING
-WEIGH
-C.G. DETERMINATION
SATF
INTEGRATED CARRIER
PACK & SHIP
-REMOVE SELECTED ITEMS, EXPERIMENTS
-FINAL INSPECTION
-PACKAGE
TRANSPORT FOR AIRLIFT TO KSC
NOTE: FLOW BASED ON AVAILABILITY OF ALL EXPERIMENTS AT DENVER

Figure 2-1

DEN 066232-02 (3-67)

1A GROUND OPERATIONS DENVER ACCEPTANCE

MARTIN MARIETTA CORPORATION
DENVER DIVISION

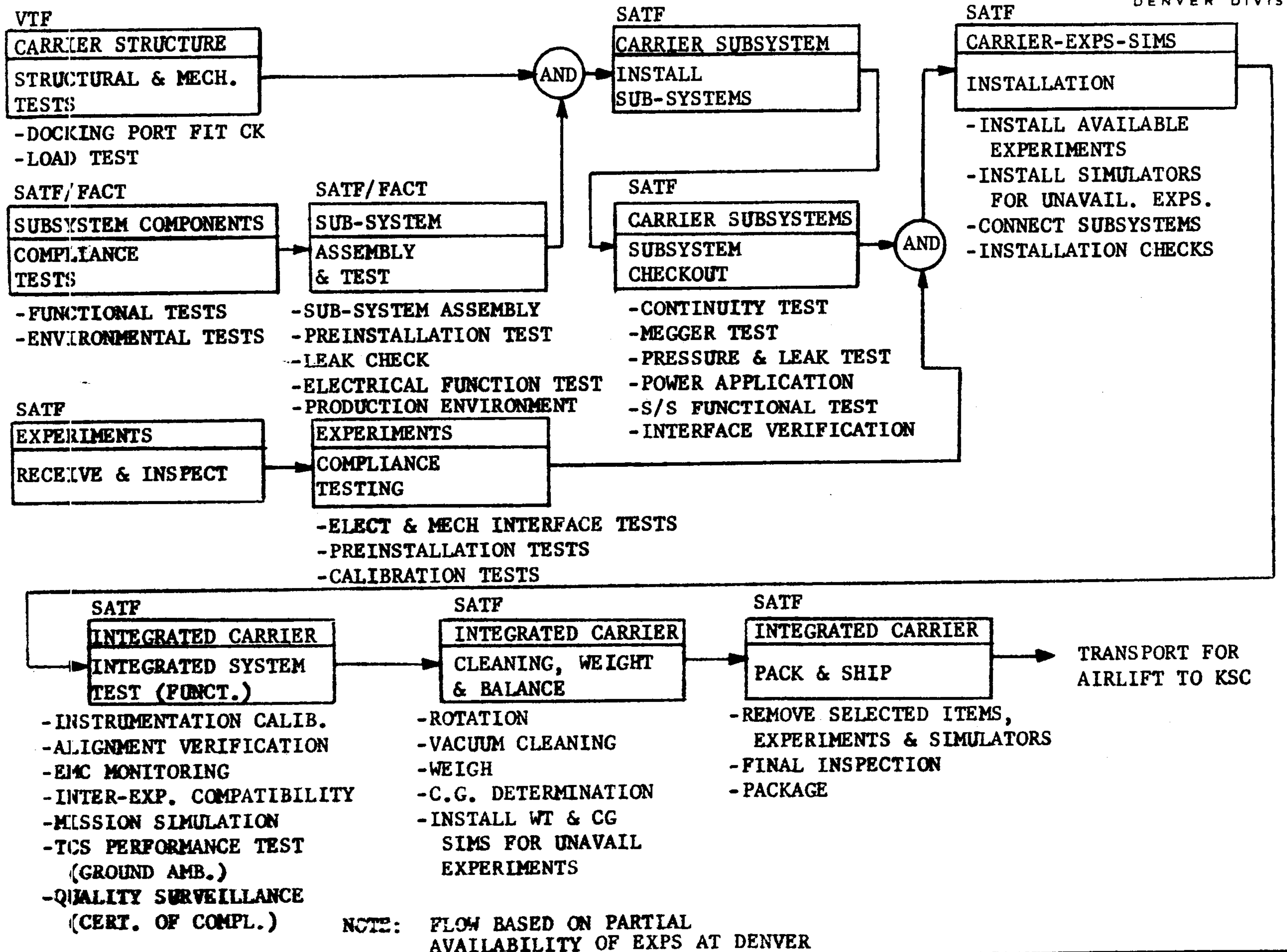


Figure 2-2

3.1.1 (Continued)

This test must be non-destructive and will be designed to verify that the flight carrier structure has the same design integrity as was demonstrated by the structural test or contractor site article.

The carrier structure will require examination to ascertain any deleterious testing effects.

3.1.2 Component - Subsystems Compliance Testing

Component acceptance testing will be required to supplement qualification testing for components as selected by the Contractor to provide the necessary additional manufacturing control for those components in which manufacturing flaws are not readily detected by normal inspection and acceptance. The components for which acceptance testing will be required are those which utilize an involved fabrication process or doubtful manufacturing technique; or which have not been previously flight qualified; and, components for which an additional safety margin is required.

Pre-installation acceptance tests of GFE subcontractor and vendor items will be required. GFE test procedures will be provided by the GFE supplier and approved by NASA and the Contractor.

Some individual carrier subsystems will be subjected to subsystems acceptance testing both ambient and environmental in conjunction with various load simulators. Leak tests will be required of those subsystems which are capable of carrying fluids or of being pressurized such as the Environmental Control System (ECS) and the carrier structure. Various components of the ECS will undergo acceptance testing, i.e. the freon boiler, radiator, accumulator, pump package, etc.

Electrical function tests will be required of the carrier components and subsystems such as the S-band and VHF transmitters, tape recorder, encoder, signal conditioner, antenna system, power inverters and voltage sensor to verify input power, calibration, data quality, transmitter power, frequency and side band energy.

3.1.3 Experiment Compliance Testing

The experiments require compliance testing to provide assurance that each experiment will perform within specific limits. Testing will be required to ensure flight readiness of each experiment, subsystem component, and of the integrated system, however, care must be taken to avoid degradation of critical components by overtesting.

Several experiments will require testing by the provision of stimuli and accepting and/or evaluating responses by means of test equipment. In addition to the test equipment, separate stimuli generators which simulate natural phenomena may be required for use in alignment, calibration and test. These experiments will include those which are of ultra violet, x-ray, infra-red and star tracking nature.

Experiments incorporating film cameras will require verification of film advance system and camera focus operation and calibration of exposure timing, lens aperture controls and image motion compensation.

3.1.4 Assembly and Integrated Systems Testing

The carrier structure, experiments and supporting subsystems will require assembly into a single integrated operable system having a high confidence level of continued successful performance. The maintenance of this high confidence level will require continuing step-by-step testing as each sub-system and experiment is installed in the carrier.

Tests will be required between interconnecting subsystems and the experiments to verify carrier/experiment compatibility.

Tests will be required to determine the end-to-end operating characteristics of the various systems to verify that the performance of each system is within the specified operating limits. These systems will include communications, power, thermal control (TCS), data management (DMS), data and control (D & C), and other supporting subsystems.

3.1.4 (Continued)

The TCS system will require a leak check to provide assurance of proper assembly and that any leakage is within specified allowable limits.

The carrier structure will require a leak check or pressure decay test to provide assurance of proper assembly and that any leakage is within specified allowable limits.

Tests will be required to verify alignment of the experiments with the carrier and to related experiments to assure proper fields of view during mission performance.

Tests will be required to verify the DMS, D &C, and power supply systems to provide assurance of proper operation and calibration. The tests will determine power source transients, intermodulation of circuitry and will also monitor critical circuits to ascertain existance of any undesired signals. The tests will be required to verify the total system accuracy and data channel assignments. The TCS system will require testing to verify that maximum and minimum load operation capabilities are within specified ground ambient operation limits. A complete mission simulation sequence of operations test will be required to verify the operation of all systems with respect to one another and that all operations will be performed within specified limits.

3.1.5 <u>Simulated Environment Carrier Acceptance Testing</u>

Simulated environmental testing will be required of the integrated carrier to provide assurance at the earliest opportunity prior to flight that the carrier systems and experiments will perform correctly in a simulated space environment. Thermal vacuum testing will require the fully assembled and integrated flight carrier to be subjected to the expected thermal and vacuum environment of space while undergoing a full integrated systems test wherein all systems are operated in mission sequence. Tests will be required to demonstrate the primary and backup features incorporated into the carrier and the carrier system performance during

3.1.5 (Continued)

power source variations. Leak or pressure decay tests will be required of the carrier structure under these environmental conditions.

The TCS system will require testing to verify that the maximum and minimum load operation capabilities are within specified space environment operation limits.

All data obtain from these tests will require evaluation for quality and to assure correlation with the anticipated results.

After completion of these tests the execution of a DD 250 will be completed for acceptance of the 1A carrier.

Simulated environment testing of the 1A carrier will be required only if a sufficient number of experiments will have been received for compliance testing and integration with the carrier to warrant the test.

3.1.6 Mass Properties

The mass properties of the carrier will require determination to provide assurance that they are within or below the prescribed limits.

The carrier weight will be determined to verify that it is below the specified limit and to enable its weight to be utilized for fuel and trajectory calculations.

The carrier center of gravity will be determined along the three reference axis of the carrier to verify that the center of gravity location is within specified limits.

3.1.7 GSE Acceptance

GSE acceptance testing will be required of each end item to verify the performance of the end item or group of end items functioning jointly is within the limits of the end item specification. Tests will be required to verify operational characteristics and

3.1.7 (Continued)

interfaces to the extent confidence will be established in these end items and will function properly when installed.

Installation and checkout (I & C) of the GSE at Denver and at KSC will be required and performed in accordance with procedures which comply with NASA approved I & C specification. I & C will be required to verify proper operation and installation of the GSE in conjunction with the facility and demonstrations will be required prior to use with the flight articles. Demonstration will constitute acceptance of the installed and tested GSE.

Generally, the GSE will require installation and use at Denver prior to subsequent shipment, installation and use at KSC.

Ground handling tools, access and transport equipment will also be required to support the operations considered in this study. These items will be required to comply with the applicable portions of this paragraph.

3.2 Baseline Acceptance Flow

3.2.1 Carrier-Experiment Acceptance at Denver

The Denver Ground Operations flow wherein all experiments are accepted and integrated with the carrier at Denver is shown in Figure 2-1.

3.2.1.1 Receiving and Inspection

a. The experiments will be packaged and shipped by the experiment manufacturer to the contractor's facility at Denver where it will be received for inspection in the Spacecraft Assembly and Test Facility (SATF). (Note: It is assumed in this study that the SATF will be completed in time and that space will be available for the purposes set forth in this study). An area in the SATF will be utilized where the experiments may be unpackaged, emplaced on test benches or support fixtures for examination

3.2.1.1 a. (Continued)

of possible damage incurred in transit.

b. Components procured from subcontractors will be received and inspected at the SATF.

c. The carrier structure and other components and subsystems will be manufactured by the Contractor in the SATF and factory.

3.2.1.2 Carrier Structural & Mechanical Tests

The required structural tests will be performed on the carrier structure within the General Purpose Lab (GPL) structures laboratory. The carrier structure will be supported in test fixtures and simulated equipment mass loads provided. The carrier will then be subjected to tests in various attitudes to provide assurance that the carrier structure is capable of withstanding the loads which will be imposed on the fully assembled carrier during handling, transport by road and air launch docking and orbital maneuvering. The limiting load factors will be as set forth in an experiment carrier specification which is to be provided at a later date.

Tests will be performed to mechanically verify the CM to carrier docking interface compatibility and the operation of the probe and drogue. The test will be performed by means of master tooling.

3.2.1.3 Component Compliance Tests

Component compliance tests, when required, will be performed in the various Contractor facilities which contain the applicable test support equipment. TCS components such as the radiators, pump package, freon boiler, cold plates and accumulators will require testing within the SSL thermal vacuum chamber to provide assurance of operation within the required environment. The TCS components will be subjected to leak tests. The leakage rates, if permissible, will be ascertained and verified to be within specified limits. Otherwise the leakage source will be determined and corrective action taken.

3.2.1.3 (Continued)

Components such as the S-band and VHF transmitters and antennas will be tested to verify transmitter power, center frequency side band energy and antenna radiated pattern at the antenna test range.

Electrical function tests will be performed on the tape recorder, encoder and signal conditioner to verify calibration recorder data quality and encoder analog linearity and bilevel gray area. Interconnecting cabling and connectors will be tested to verify signal-to-pin continuity, and connector indexing. These tests will be performed in the SATF.

Support for testing of additional components may be performed at the GPL and factory test laboratories.

3.2.1.4 Subsystem Assembly and Test

Subsystem acceptance tests will be performed generally in the facility in which they will be manufactured and assembled. These areas are primarily the contractor's factory and SATF.

Testing will be performed on assemblies which will be comprised of previously tested components and minor subassemblies at the next higher level. The TGS radiators, accumulators, freon boiler, cold plates and pump packages were previcusly tested as components and after assembly additional leak, pressure and flow tests will be performed to provide assurance of proper operation. Tests will be performed to verify the subassembly buildup of the DMS as the encoder, signal conditioner, tape recorder. S-band and VHF transmitters antennas are interconnected into various operable subsystems. Similar tests will be performed during the assembly of the D & C and power supply systems. The tests will include continuity and electrical function tests wherein the sub-systems may be assembled with the appropriate test equipment and necessary load or experiment simulators. The tests will be performed to verify subsystem operation prior to interconnection into the final assembly.

3.2.1.5 Experiment Compliance Test

Experiment compliance tests will be performed within an area provided in the SATF. The area provided will accommodate the assembly, calibration and test operations required to assure proper operation. The area will also accommodate examination of malfunctioning experiments to isolate the malfunctioning component and perform either minor repair or black box replacement and subsequent verification tests. These tests may require support from other areas such as the metrological laboratory and the antenna test range. Testing will be performed at the highest experiment subsystem or system level possible in keeping with the need for a high confidence level.

Tests will be performed upon the ultra-violet, x-ray, and infra-red experiments by means of externally applied stimuli, which simulate natural phenomena and accepting and/or evaluating responses by means of test equipment to verify alignment, calibration and operation.

Tests will be performed on the experiments which incorporate film cameras to verify film advance system and camera focus operation, and the calibration of exposure timing, lens aperture controls and image motion compensation.

3.2.1.6 Carrier Assembly

An area within the SATF will be provided where the carrier structure will be supported vertically by a support fixture in a normal launch attitude for the attachment of subsystems and components. The carrier will be supported from the normal carrier to SLA attachment points. The various components and subassemblies comprising the TCS, DMS, D & C and power supply systems with interconnecting cabling and piping will be installed.

3.2.1.7 Carrier Subsystems Test

The area provided for carrier assembly in the SATF may be used for the performance of the carrier subsystems tests with the addition of the required test support equipment.

3.2.1.7 (Continued)

Tests will be performed to assure that end-to-end operating characteristics of the TCS, DMS, D & C and power supply systems are within specified limits.

Leak, pressure and flow tests will be performed on the TCS subsystem to assure proper installation and subsequent operation. Tests will be performed to verify the DMS, D & C and power supply systems to provide assurance of proper operation and calibration.

Interface tests will be performed to assure compatibility of the interconnecting subsystems prior to systems operation and experiment installation.

3.2.1.8 Carrier-Experiment Installation

An area will be provided in the SATF wherein the carrier will be mounted on a support base in a vertical attitude such that the experiments may be installed from underneath. The experiments will be raised into position and attached to the carrier. The interconnecting systems will be connected and the interface compatibility verified. The experiments will be optically aligned with the carrier and with related experiments by means of reference mirrors mounted on each experiment and by ground optical alignment equipment.

3.2.1.9 Carrier Integrated Systems Test (Ambient)

An area will be provided in the SATF wherein the carrier will be mounted on a support base in a vertical attitude and the test support equipment will be installed and operational accepted. GSE will be installed to support the test and attached to the carrier. Carrier power will be provided from the ground power distribution center (PDC). The D & C panel will be connected to the carrier for control and status monitoring. Ground cooling equipment will be connected to the TCS to provide servicing, flow rate test capability, and ground cooling capability to enable ground ambient operation testing of the carrier TCS. The TCS radiators will not be functional during ambient testing thereby necessitating use of the ground cooling equipment. Tests will be performed to verify that the TCS maximum

3.2.1.9 (Continued)

and minimum load operation capabilities are within specified ground ambient operation limits.

Tests will be performed to verify the DMS, D & C and power supply systems to provide assurance of proper operation and calibration. EMI monitoring equipment will be utilized during the integrated systems and mission simulation tests. Tests will be performed to determine power source transients, intermodulation of circuitry and the existance of magnetic fields as well as to monitor critical circuits for undesired signals. The tests will be performed to determine experiment response to stimulus and the cross coupling effects of the stimulus. An RF open loop test will be performed to verify the performance of the carrier antennas with carrier systems operating and to verify the lack of interference by radiated signals upon the carrier systems.

Each carrier system will be operated and tested on an individual basis prior to the performance of the integrated system test. Upon successful completion of these tests an integrated systems test will be performed using the programmed mission sequence of events. All systems will be operated in such a manner as to provide an ambient simulated mission. The tests will be performed to demonstrate primary and backup features of the carrier systems and to demonstrate the carrier system performance during power source variations. Complete data evaluation will be performed to provide assurance of data quality and correlation with the anticipated results.

3.2.1.10 Carrier Integrated Systems Test (Space Environment)

The simulated environment testing of the integrated carrier will be performed in the SSL thermal vacuum chamber.

The carrier will be prepared for test in the test preparation area adjacent to the vacuum chamber. The carrier will be supported from the chamber lid by cables and the required test and instrumentation attached by cabling from the lid penetration to the carrier. The supporting GSE and test equipment will be installed and tested prior to use and will require interface verification testing of the test setup. Prior to insertion of the carrier into the vacuum chamber a preliminary test will be performed to assure proper interconnections and equipment performance. The carrier will then be inserted in the chamber, the lid emplaced and the appropriate space environment simulated by means of the chamber cold wall and IR source. The carrier will then undergo a full integrated systems test wherein all systems and experiments will be operated in mission sequence. The TCS will be operated under maximum and minimum load conditions in this environment to provide assurance that the TCS operational capability is within specified limits.

A carrier pressure decay test will be performed to assure that the leakage rate is below the specified limit.

The tests will be performed to demonstrate primary and backup features of the carrier systems and to demonstrate the carrier system performance during power source variation. Complete data evaluation will be performed to provide assurance of data quality and correlation with the anticipated results.

3.2.1.11 Carrier Cleaning, Weight and Balance

Carrier cleanliness is an item for concern and during and after each step, installation or test, care will be exercised to prevent the introduction of unwarranted articles, particles, solids or fluids. However, additional cleaning will be performed prior to thermal vacuum chamber testing to minimize out gassing

3.2.1.11 (Continued)

and subsequent deposition of undesired materials on optical lenses and other equipment. Cleaning will be performed in the SATF prior to packaging and shipping. Cleaning will be done by means of solvents and vacuuming.

After thermal vacuum testing the carrier will be taken to an area in the SATF for determination of the carrier weight and the location of the center of gravity along the three reference axis of the carrier. The carrier will be supported in test fixtures in the vertical and horizontal attitudes thereby enabling the weight and c.g. location to be determined by means of load cell reactions.

3.2.1.12 Pack and Ship

An area in the SATF will be provided where selected experiments, batteries and other ship loose items will be removed from the carrier. These items will be packaged for shipment by road and air.

The carrier will be mounted upon a transport pallet and secured. A breather will be installed in the carrier docking port to prevent the entry of dirt particles and water vapor while maintaining an ambient atmospheric pressure in the carrier during transport by road and air. A protective cover will be installed to protect the carrier and carrier insulation from ambient weather conditions encountered in transit.

3.2.1.13 Transport

Transport from the Contractor's facility will be by semi-trailer and tractor over the roadways to the airport. The carrier on its transport base will be loaded onto the 'Pregnant Guppy' aircraft and secured to the aircraft for subsequent transport to the KSC skid strip. Loading into the aircraft will require the use of a mobile crane and handling slings to off-load the carrier and its transport base onto the aircraft loading pallet. After the carrier and transport base are secured to the pallet, the pallet is elevated by means of an elevating platform truck (GFE) to the aircraft deck level and

3.2.1.13 (Continued)

rolled into the aircraft. The pallet is secured to the aircraft and auxilliary tie downs from the carrier to the aircraft are installed. Other items are loaded onto the aircraft deck and secured for flight.

At KSC off loading is performed in the reverse manner to loading sequences by means of similar equipment.

3.2.2 Partial Experiment Acceptance at Denver

The Denver Ground Operation flow wherein only part of the experiments are accepted and integrated with the carrier at Denver is shown in Figure 2-2.

3.2.2.1 Receiving and Inspection

a. The experiments and experiment simulators will be packaged and shipped by the experiment manufacturers to the Contractors facility at Denver where they will be received for inspection in the SATF. An area in the SATF will be utilized where the experiments and simulators may be unpackaged, emplaced on test benches or support fixtures for examination of possible damage incurred in transit.
b. Same as 3.2.1.1.b
c. Same as 3.2.1.1.c

3.2.2.2 Carrier Structural & Mechanical Tests

Same as 3.2.1.2

3.2.2.3 Component Compliance Test

Same as 3.2.1.3

3.2.2.4 Subsystem Assembly and Test

Same as 3.2.1.4

3.2.2.5 Experiment Compliance Test

Same as 3.2.1.5

3.2.2.6 Carrier Assembly

Same as 3.2.1.6

3.2.2.7 Carrier Subsystems Test

Same as 3.2.1.7

3.2.2.8 Carrier - Experiment Installation

Same as 3.2.1.8 with the addition of the following:

'Simulators will be required for those experiments which will not be received, tested and integrated with the carrier at Denver. The simulators will provide continuity of input and output signals in response to the carrier systems. The simulator will replace the experiment on the carrier structure and provide similar interface connectors for assembly into the carrier systems.'

3.2.2.9 Carrier Integrated Systems Test (Ambient)

Same as 3.2.1.9 with the addition of the following after the second sentence.

'Simulators will be utilized for unavailable experiments to provide proper electrical response and heat loads during test.'

3.2.2.10 Carrier Integrated Systems Test (Space Environment)

This test will not be performed unless:

a. The number of experiments received and integrated with the carrier justify the test performance when supported by experiment simulators.
b. The assurance level to be obtained using experiment simulators is sufficiently above that obtained when testing the contractor site article.
c. The assurance level to be gained justifies the cost of the test.

If the test is to be performed the paragraph is the same as 3.2.1.10 with the addition of the following after the second sentence:

3.2.2.10 Continued

'Simulators will be utilized for unavailable experiments to provide proper electrical response and heat loads during test.'

3.2.2.11 <u>Carrier Cleaning, Weight and Balance</u>

Same as 3.2.1.11

3.2.2.12 <u>Pack and Ship</u>

Same as 3.2.1.12

3.2.2.13 <u>Transport</u>

Same as 3.2.1.13

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

4.1.1 An adequate 1A Carrier acceptance can be performed even with some missing experiments as specified by using experiment simulators.

4.1.2 Use of portable automatic ground checkout systems would enhance the capability to perform acceptance testing with the 1A proposed schedule constraints.

4.1.3 If a significant number of experiments which currently are considered as available at Denver should slip delivery, the usefulness of performing an environmental test should be re-evaluated.

4.2 Recommendations

It is recommended that continuing analysis be performed to define component and experiment compliance testing, subsystem test and integrated functional and environmental system test.

PR-29-27

STUDY REPORT

KSC GROUND OPERATIONS PLAN

AAP/PIP EARLY APPLICATIONS

Contract NAS 8-21004

8 September 1967

Prepared by Paul Hixenbaugh
Paul Hixenbaugh

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MARTIN MARIETTA CORPORATION
Denver Division

MARTIN MARIETTA CORPORATION
DENVER DIVISION

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FIGURES

1. INTRODUCTION

1.1 Purpose - This study report provides an early identification and delineation of an orderly sequence of operations whereby the 1A carrier and GSE may be integrated with the normal Apollo launch operations in an efficient and logical manner.

1.2 Objectives - The objectives of this study were as follows:

a. Provide a sequence of operations at KSC to integrate the carrier and the Apollo spacecraft which can be used as a baseline for identifying GSE, support systems, and test crew requirements.

b. Provide a sequence of operations having a minimum cost and schedule impact.

c. Provide maximum practical utilization of existing KSC facilities and supporting operations.

d. Provide a high confidence level through a building block, system by system, approach of assurance testing.

e. Identify areas which may affect cost, schedules or cause delay and will require further study. Where practical, provide alternate recommendations for additional investigation.

2. SUMMARY

The results of this study are summarized in the two block flow sequences shown in Figures 2-1 and 2-2, and the time line shown in Figure 2-3.

The sequence of operation commences with the transport of the carrier and experiments at KSC, and continues through the required sequences to the launch of the booster vehicle.

A block flow sequence is provided in Figure 2-1 wherein it is assumed that all experiments will be integrated with the carrier prior to shipment to KSC.

An alternate block flow is provided in Figure 2-2 wherein it is assumed several experiments will arrive late and will require compliance testing and integration with the carrier at KSC.

The time line shown in Figure 2-3 presents a schedule of events based upon a forty hour work week over a four month period.

1A CARRIER KSC GROUND OPERATIONS

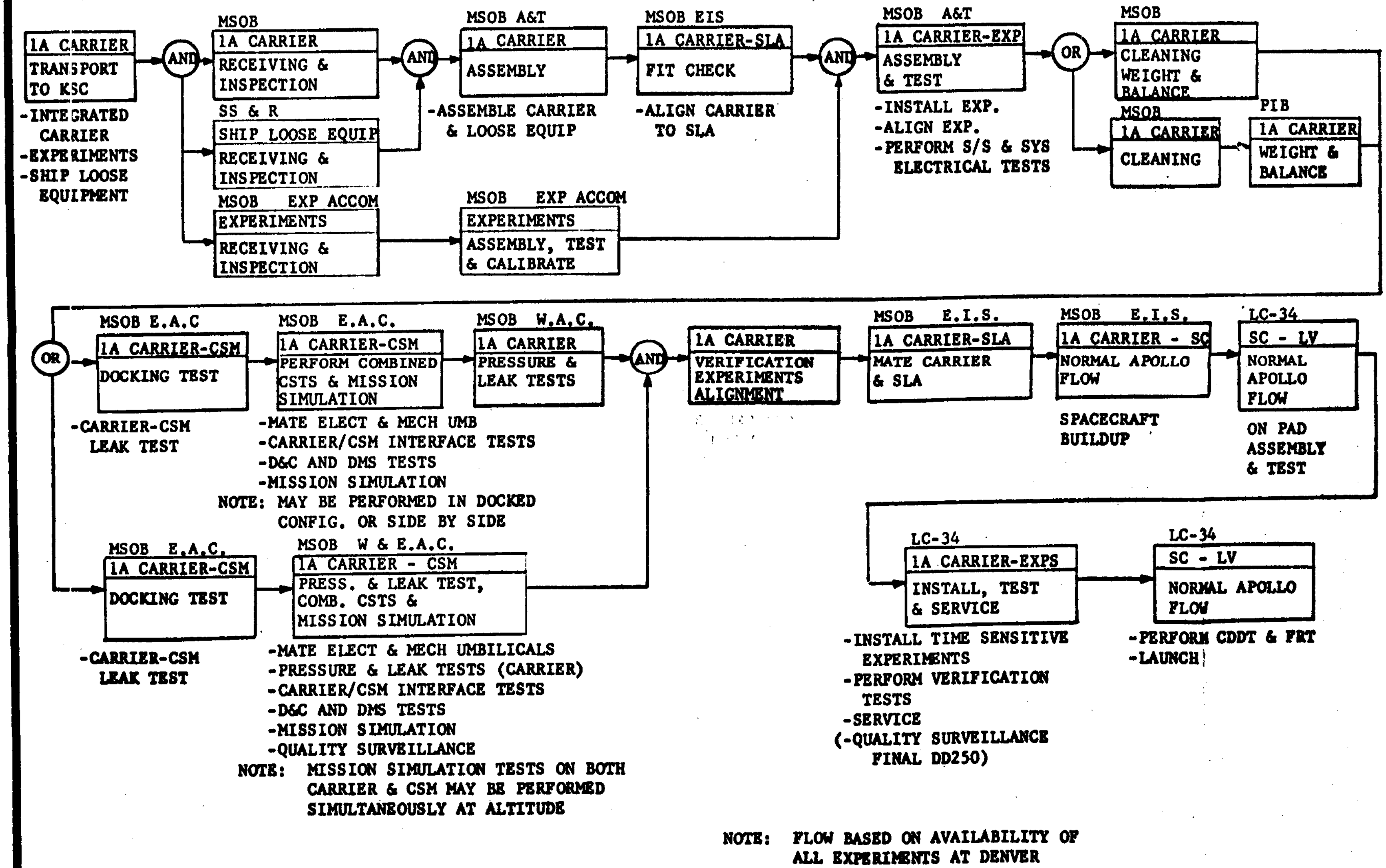

Figure 2-1

1A CARRIER KSC GROUND OPERATIONS

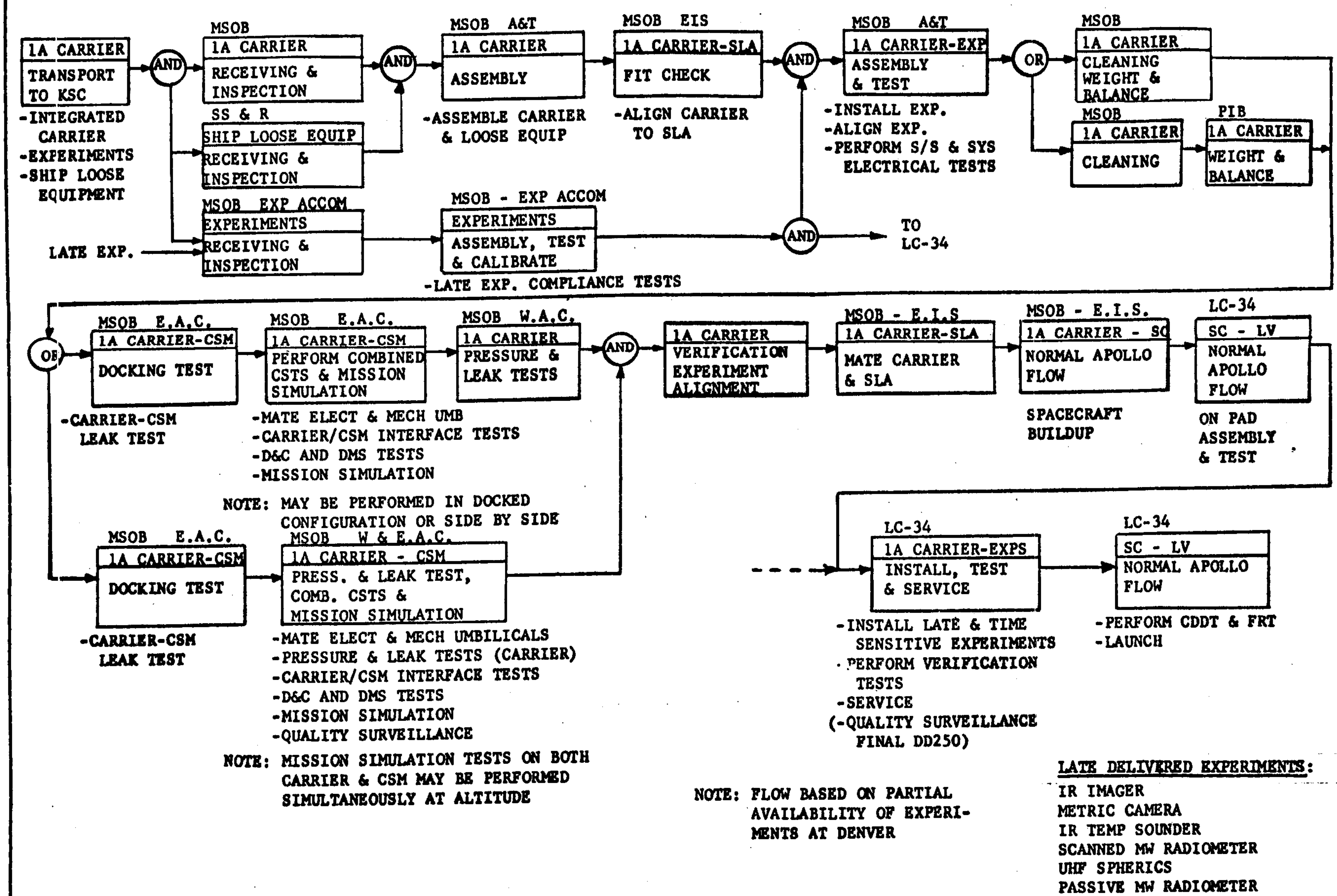

Figure 2-2

DEN 066232-02 (3-67)

1A - KSC GROUND OPERATIONS SUMMARY
4 MONTH SCHEDULE - 5 DAY WEEK

MARTIN MARIETTA CORPORATION
DENVER DIVISION

DAYS	
T-88	ARRIVAL AT KSC, CARRIER WITH S/S & SOME EXPERIMENTS
T-87	CARRIER - TO - SLA FIT CHECK
T-86	EXPERIMENT INSTALLATION
T-82	CARRIER SYSTEM TEST
T-75	CARRIER/CSM EMI TEST
T-68	CARRIER/CSM ELECT/MECH DOCKING TEST
T-60	EXPERIMENT ALIGNMENT CHECKS
T-58	WT & CG TEST, CLEANING
T-50	CARRIER/SLA MATE
T-46	APOLLO SPACECRAFT BUILDUP
T-39	MATE S/C TO LV
T-35	S/C SYSTEMS TEST
T-25	PLUGS IN TEST
T-22	PLUGS OUT TEST
T-6	COUNTDOWN DEMONSTRATION TEST
T-3	START COUNTDOWN
T-0	LAUNCH

Figure 2-3

3. KSC GROUND OPERATIONS

KSC ground operations are those which must be performed to assemble, verify, service, handle and transport the carrier and experiments prior to launch to provide a high confidence level in the proper functioning of the integrated carrier.

3.1 Requirements and Considerations - The following requirements and considerations, and the previously stated objectives, provide the parameters for this study.

3.1.1 1A Carrier Ground Operations - The ground operational sequences must consider the operational intent and capabilities of the various facilities within the KSC industrial area. Particularly the Manned Spacecraft Operation Building (MSOB) wherein the Apollo CM, SM, SLA and other equipment undergo assembly, verification testing, and integration into a combined spacecraft prior to transport to the launch facility for assembly on the launch vehicle and subsequent launch. Consideration must also be given to the requirements of the carrier, experiments and subsystems that will need support such as floor space, commodities, support from various laboratories and accommodation areas.

The operational sequences for integration of the LM and the LM & SS into the normal Apollo flow as prepared by NASA and TRW must be examined to determine its adaptability for the 1A carrier wherein a similar approach may be required.

The operations and tests to be performed with the carrier and CSM will provide a minimum impact on the nominal Apollo test flow.

The tests to be performed will verify physically and functionally all interfaces between the CSM and the carrier.

Items which may be susceptable to the loads and environment induced by handling and transport of the integrated 1A carrier such as sensitive optical experiments (none identified as yet), the tape recorder, the docking collar seal, and the carrier flight batteries will require removal from the carrier for individual packaging and shipment. Perishable portions of the experiments will be provided directly to KSC from the supplier. These items must be reinstalled and the affected subsystem verified for proper operation. The level of testing will be performed at the highest component level consistent with the establishment of the required confidence level.

3.1.1 (Continued)

Cleanliness levels must be established and/or maintained, and the weight and center of gravity determined to be within prescribed limits to provide further assurance of flight readiness.

Consideration must also be given to the standardization of procedures to be used at Denver and KSC as well as the maximum practical use of the same GSE at both locations. Consideration will be required for compliance with KSC safety requirements, procedures and standards, as well as the use of trained and certified personnel.

Flexibility must be considered in test planning with regard to the utilization of specific KSC facilities.

3.1.2 Normal Apollo Flow Interface - Verification testing of the physical and functional interfaces between the carrier and the CSM will be required prior to final Apollo spacecraft assembly. Testing of these interfaces will require careful scheduling to minimize impact on the CSM test sequences.

Physical mating or docking tests with the CSM and SLA will be performed at the earliest opportunity to provide assurance of proper fit, and, if required, allow sufficient time for any corrective action.

Leak or pressure decay testing of the CM - Carrier while in a docked configuration will be required.

Verification testing of the carrier individually and in conjunction with the CSM must be completed prior to final integration of the carrier and the Apollo spacecraft.

The use of simulators for late arriving and time sensitive experiments must be considered to permit timely testing without creating unwarranted delays or necessity for rescheduling.

3.1.3 Experiment Acceptance at KSC - Ideally, experiment acceptance will not be performed at KSC as all experiments will have been received, compliance tested, integrated with the carrier and accepted at the contractor's Denver facility. However, a survey of tentative experiment delivery dates reveals the following proposed experiments will require these operations to be performed at KSC:

3.1.3 (Continued)

IR Imager

Metric Camera

IR Temperature Sounding

Scanned MW Radiometer

UHF Spherics

Passive MW Radiometer

The requirements of each late arriving experiment for inspection, assembly, servicing and compliance testing will require examination and analysis. A basic accommodation area wherein the experiment(s), handling, test and servicing equipment may be installed and operated must be provided. Appropriate power supplies and support services must also be available.

The building block approach to acceptance testing by starting with components, building to subsystems or systems, and finally integration with the carrier will be required during experiment acceptance at KSC.

3.1.4 Experiment Acceptance at Denver - Experiments which are available will be accepted and integrated with the carrier at Denver. The experiment acceptance operations at Denver will be similar to those at KSC and will be the subject of a separate study report. (Reference PR-29-26, Flight Article and GSE Acceptance Study Report.)

3.1.5 GSE Acceptance - GSE acceptance testing will be required of each end item to verify the performance of the end item, or group of end items, functioning jointly and is within the limits of the end item specification. Tests will be required to verify operational characteristics and interfaces to the extent confidence will be established in these end items and will function properly when installed.

Installation and checkout (I&C) of the GSE at the using location will be required and performed in accordance with procedures which comply with NASA approved I&C specifications. I&C will be required to verify proper operation and installation of the GSE in conjunction with the facility and demonstrations and will be required prior to use with the flight articles. Demonstration will constitute acceptance of the installed and tested GSE.

3.1.5 (Continued)

Generally, the GSE will require installation and use at Denver prior to subsequent shipment, installation and use at KSC.

Ground handling, tools, access and transport equipment will also be required to support the operations considered in this study. These items will be required to comply with the applicable portions of this paragraph.

3.2 Baseline Operations Flow

3.2.1 Experiment Acceptance at KSC - The KSC Ground Operations flow wherein late arriving experiments are accepted at KSC is shown in Figure 2-2.

3.2.1.1 Receiving and Inspection -

a. The carrier will be received in an unloading area near the west end of the MSOB low bay where the initial inspection will be performed to ascertain possible damage incurred during transit. The protective cover will be removed to facilitate the inspection and to permit installation of handling equipment for movement to the assembly and test (A&T) area where the inspection will be completed.

b. The ship-loose equipment will be received in the Supply, Shipping and Receiving (SS&R) Building where the equipment will be unpacked and examined for possible damage incurred in transit. The equipment may also be stored herein until required for installation.

c. The experiments, which are late arriving or packaged and shipped separately, will be received in an accommodation area or laboratory where the experiments may be unpackaged, emplaced on test benches or support fixtures and inspected for possible damage incurred in transit. The area will accommodate the experiment GSE equipment and other test equipment required to ascertain possible damage functionally.

3.2.1.2 Experiment Assembly, Test and Calibration - An area will be provided to accommodate the assembly, calibration and test operations required by the experiments to assure proper operation. Compliance tests will be performed on the late arriving and time sensitive experiments prior to integration with the carrier. The area will also accommodate examination of malfunctioning experiments to isolate the

3.2.1.2 (Continued)

malfunctioning component and perform other minor repair or black box replacement and subsequent verification tests. The performance of these tests may require support from other areas such as the metrological laboratory and the antenna range. Testing will be performed at the highest experiment subsystem or system level possible in keeping with the establishment of a high level of confidence.

Time sensitive experiments or components of the experiments, such as the human cell and frog otolith experiments, will be received and tested prior to integration with the carrier at LC-34 during the later stages of the countdown. Other experiments or components after test will be integrated with the carrier either in the MSOB or at the launch complex earlier in the countdown.

3.2.1.3 Carrier Assembly - An area within the MSOB low bay area will be provided where the carrier will be supported vertically by a support fixture in a normal launch attitude. The area will require the services of a crane for the basic movement and handling of the carrier and the installation of equipment. Verification of proper installation of these items will be performed in this area.

3.2.1.4 Carrier - SLA Fit Check - A fit check will be performed to assure proper fit and alignment of the carrier with the SLA at the attachment interface and that adequate clearance is available between the carrier and the SLA. It is intended that these tests be performed in the MSOB East Integration Stand (E.I.S.) where adequate support equipment and external platforms are existing. The fit check must be performed as early in the sequence of operations as practical to permit time for any required modifications or adjustments. The area will require the services of a crane for the basic movement and handling of the carrier and SLA.

3.2.1.5 Carrier - Experiment Assembly - An assembly area will be provided within the MSOB low bay area where the carrier will be mounted on a support base in a vertical attitude such that the experiments may be installed from underneath. The experiments will be raised into position and attached to the carrier. The interconnecting systems will be connected and the interface compatibility verified. The experiments will be optically aligned with the carrier and with related experiments by means of reference mirrors mounted on each experiment and by ground optical alignment equipment.

3.2.1.6 Carrier Subsystem/System Tests - The area provided for carrier-experiment assembly in the MSOB may also be utilized for carrier subsystem/system tests. The carrier will be mounted upon a support base in a vertical attitude and the test support equipment will be installed and operationally accepted. GSE will be installed to support the test and attached to the carrier. Carrier power will be provided from the ground power distribution center (PDC). The D&C panel will be connected to the carrier for control and status-monitoring. Ground cooling equipment will be connected to the TCS to provide servicing and ground cooling capability to enable operation of the carrier TCS. The TCS radiators will not be functional during ambient testing thereby necessitating use of the ground cooling equipment.

Tests will be performed to verify the DMS, D&C and power supply systems to provide assurance of proper operation and calibration. EMI monitoring equipment will be utilized during the subsystems and systems tests. Tests will be performed to determine power source transients, intermodulation of circuitry, and the existance of magnetic fields as well as to monitor critical circuits for undesired signals. The tests will be performed to determine experiment response to stimulus and the cross coupling effects of the stimulus.

3.2.1.7 Carrier Cleaning, Weight and Balance - After completion of carrier assembly and test and prior to the leak tests in the altitude chamber, the carrier will require cleaning. It is proposed that adapters be provided for use with the NAA cleaning fixture in the MSOB where the carrier may be positioned, rotated and vacuum cleaned. Foreign particles and articles must be removed from the carrier interior, and the exterior carrier surfaces cleaned. Optical equipment lenses must be cleaned and protected from accumulation of dirt.

The weight of the fully assembled carrier must be obtained and verified within specified limits. The location of the center of gravity of the fully assembled carrier must be determined along the three reference axis to be within prescribed limits. The equipment utilized during weight and balance determination is relatively portable and readily assembled for test. The operations are dependent upon a crane for test set up and handling of the carrier. The test location however can be in available floor space within the MSOB or in the Pyrotechnic Installations Building (PIB) where similar tests are performed.

3.2.1.7 (Continued)

The weight and balance operations can be performed after assembly and test of the fully assembled carrier and before final integration and assembly of the Apollo spacecraft.

3.2.1.8 Carrier - CSM Docking and Leak Test - A physical interface test of the carrier-CM docking port must be provided to assure the capability of interconnecting these items during the mission. A pressure leak test will be required to verify the effectiveness of the carrier-CM seal and to determine the leakage rate.

This plan assumes that the CM is mounted on the SM in a vertical launch attitude and that the carrier must be placed in an inverted attitude directly above the CM and lowered for test. The CSM is assumed to be in the east altitude chamber.

The docking and leak test must also be accomplished early in the sequence of operations to permit time for any required modifications or adjustments.

The performance of this test will require the availability of the CSM, and a crane of adequate hook height to permit stacking of the carrier on the CSM and accessibility to the docking interface.

3.2.1.9 Carrier - CSM CSTs and Mission Simulation - Verification testing of the combined carrier and CSM systems must be performed to provide assurance of systems compatibility and function. The CSTs and mission simulation tests may be performed while the carrier is docked to the CSM thereby eliminating interconnecting cabling between the carrier and CSM, while providing a near mission configuration. Or, the tests may be performed in a side-by-side configuration by means of interconnecting cabling between the carrier and the CSM. The CSM installed in the east altitude chamber and the carrier in the adjacent aisle space. A third configuration is possible where the carrier is installed in the west altitude chamber and connected to the CSM through instrumentation cabling. The last configuration with the carrier installed in the west altitude chamber is preferred.

The carrier and CSM systems will be interconnected by marriage cables and the test support equipment installed and interfaces verified. Carrier power will be provided from the ground PDC.

3.2.1.9 (Continued)

The D&C panel will be connected for control and status monitoring. Ground cooling equipment will be connected to the TCS to provide servicing, flow rate test, and ground cooling capability to enable operation of the carrier TCS at ground ambient temperature. The TCS radiators will not be functional during ambient testing thereby necessitating the use of the ground equipment. Tests will be performed to verify that the TCS maximum and minimum load operation capabilities are within specified ground ambient operation limits.

EMC monitoring equipment will be utilized during the CSTs and mission simulation tests. Tests will be performed to determine power source transients, intermodulation of circuitry and the existance of magnetic fields as well as to monitor critical circuits for undesired signals. The tests will be performed to determine experiment response to stimulus and the cross coupling effects of the stimulus.

Each carrier system will be operated and tested on an individual basis prior to the performance of the CSTs and mission simulation tests. Upon successful completion of the individual tests CSTs will be performed using the programmed mission sequence for the combined CSM/carrier. All systems will be operated in such a manner as to provide an ambient simulated mission. The tests will be performed to demonstrate primary and backup features of the carrier systems and to demonstrate the carrier system performance during power source variation. Complete data evaluation will be performed to provide assurance of data quality and correlation with the anticipated results.

3.2.1.10 Carrier Pressure and Leak Tests - Pressure decay or leak tests will be performed on the carrier in the west altitude chamber in the MSOB. The test will be performed to verify that the carrier leakage rate is below the specified allowable rate.

3.2.1.11 Experiment Alignment Verification - The precise alignment of each experiment is critical and may have been disturbed inadvertently during testing and handling. Verification of experiment alignment will be performed after completion of all testing and prior to final assembly of the carrier with the SLA. The alignment verification will be performed in the carrier A&T area by means of the reference mirrors mounted on each experiment and by ground optical alignment equipment.

3.2.1.12 Carrier - SLA Integration - The integration of the SLA and the carrier is an initial operation in the final Apollo spacecraft buildup. The carrier will be installed on the lower SLA and alignment verified, the carrier to SLA attachment hardware installed and the upper SLA emplaced. The carrier to SLA ordnance less the initiators will also be installed. The integration of the carrier with the upper and lower SLA will be performed in the MSOB east integration stand (E.I.S.). The area will require the services of a crane to provide the required handling and emplacement of the carrier and SLA. External and internal access platforms will be utilized. The carrier docking port protective seal will also be installed.

3.2.1.13 Apollo Spacecraft Buildup - After completion of the carrier - SLA integration the next operation sequences that will be performed are part of the normal Apollo spacecraft buildup of the CSM onto the SLA and do not concern the carrier.

After completion of the normal Apollo spacecraft buildup and verification in the MSOB E.I.S. the assembled spacecraft will be positioned upon a semitrailer and transported to Launch Complex - 34 (LC-34). The exterior environmental conditions encountered during transport may require air conditioning to be provided within the SLA.

3.2.1.14 Launch Vehicle - Spacecraft Buildup - Assembly of the combined Apollo spacecraft (SLA, carrier, CSM) and LES on the assembled launch vehicle at LC-34 is part of the normal Apollo sequence and does not affect the carrier. Launch vehicle and spacecraft integration tests will be performed to verify proper assembly and interfaces. However, the environment within the SLA about the carrier will be provided by means of an air conditioning supply umbilical from the umbilical tower to the Instrumentation Unit (I.U.) as soon as the umbilical may be connected. The environment will be maintained by means of the umbilical until launch.

3.2.1.15 Carrier - Experiment Installation, Test and Service - Experiments which were not installed in the carrier at the MSOB by reason of late delivery or time sensitivity will be installed in the carrier at LC-34. These experiments or time sensitive components, as well as the flight batteries, experiment expendables such as films, and replacement components will also be installed. The systems into which

3.2.1.15 (Continued)

these items will be installed will be tested to provide verification of proper installation and operation. Experiments or components which require alignment will be aligned similarly to the alignment performed in the MSOB. The integrated carrier system tests will be performed in preparation for the Countdown Demonstration Test (CDDT) and the Flight Readiness Tests (FRT). This test will be performed with the use of antenna hats to relay radiated signals from the carrier antennas within the SLA to ground relay station.

The operable carrier-experiment components which require late installation will be installed and functionally verified prior to any Apollo combined launch vehicle - spacecraft tests in which the carrier systems are expected to participate.

The operation of the carrier systems at the launch complex will be supported by means of a Freon Support Unit (F.S.U.) connected to the carrier TCS boilers by means of a ground umbilical from the umbilical tower (U.T.). The umbilical will be removed manually.

Access to the carrier will be provided within the SLA by means of portable access platforms supported by the SLA. These platforms will provide access for component and experiment installation, alignment, servicing and testing. Access to the SLA will be provided by the mobile service structure (MSS) until approximately T-8 hours. Access to the IU will be provided by the UT swing arm.

Servicing equipment and test equipment such as the TCS coolant service unit (CSU) and vacuum pump will be supported near the SLA by the MSS access platforms and connected to the carrier systems by ground umbilicals.

These functions will be performed during periods which will not provide interference with other Apollo operations such as propellant loading of the launch vehicle and spacecraft.

The internal SLA environment will be maintained by the IU air conditioning umbilical until launch.

3.2.1.16 Countdown and Launch - During the later stages of the Apollo flow, a CDDT and FRT will be performed to demonstrate flight readiness. The countdown and launch of the spacecraft will be normal Apollo flow sequences with the carrier inoperable until docked and mated to the CSM.

3.2.2 Experiment Acceptance at Denver - The KSC Ground Operations flow wherein all experiments are accepted and integrated at Denver is shown in Figure 2-1.

3.2.2.1 Receiving and Inspection

a. Same as 3.2.1.1.a
b. Same as 3.2.1.1.b
c. Same as 3.2.1.1.c

3.2.2.2 Experiment Assembly, Test and Calibration - An area will be required to accommodate the assembly, calibration and test operation of ship separate experiments and to accommodate examination of malfunctioning experiments to isolate the malfunctioning component and perform either minor repair or black box replacement and subsequent verification tests.

The performance of these tests may require support from other areas such as the metrology laboratory and the antenna range. Testing will be performed at the highest subsystem or system level possible in keeping with the provisions of a high level of confidence.

Time sensitive experiments or components of the experiments such as the human cell and frog otolith experiments will be received and tested prior to integration with the carrier at LC-34 during the later stages of the countdown. Other experiments or components after test will be integrated with the carrier either in the MSOB or at the launch complex.

3.2.2.3 Carrier Assembly

Same as 3.2.1.3

3.2.2.4 Carrier - SLA Fit Check

Same as 3.2.1.4

3.2.2.5 Carrier - Experiment Assembly

Same as 3.2.1.5

3.2.2.6 Carrier Subsystem/System Tests

Same as 3.2.1.6

3.2.2.7 Carrier Cleaning, Weight and Balance

Same as 3.2.1.7

3.2.2.8 Carrier - CSM Docking and Leak Test

Same as 3.2.1.8

3.2.2.9 Carrier - CSM CSTs and Mission Simulation

Same as 3.2.1.9

3.2.2.10 Carrier Pressure and Leak Test

Same as 3.2.1.10

3.2.2.11 Experiment Alignment Verification

Same as 3.2.1.11

3.2.2.12 Carrier - SLA Integration

Same as 3.2.1.12

3.2.2.13 Apollo Spacecraft Buildup

Same as 3.2.1.13

3.2.2.14 Launch Vehicle - Spacecraft Buildup

Same as 3.2.1.14

3.2.2.15 Carrier - Experiment Installation, Test and Service

Same as 3.2.1.15 where references to late arriving experiments are deleted.

3.2.2.16 Countdown and Launch

Same as 3.2.1.16

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

4.1.1 KSC can support a February 1969 launch by using a normal Apollo 4 month KSC operations schedule wherein some experiments will be installed at KSC.

4.1.2 KSC could support a January 1969 launch by implementing a 3 month KSC operation schedule wherein the first 50 working days would require two shift operation.

4.1.3 In general, carrier/CSM EMI and docking tests will be constrained by CSM availability.

4.2 Recommendations - It is recommended that additional analysis be performed to further define the methods and timelines associated with KSC experiment laboratory testing, installation and system testing.

PR 29-28

TRADE STUDY REPORT

SUPPORT CAMERA SELECTION

AAP/PIP EARLY APPLICATIONS

Contract NAS 8-21004

August 30, 1967

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Approved by: R. P. Porter-Goff

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1. INTRODUCTION

The purpose of this report is to summarize the analysis undertaken to select a 70mm support camera system for the 1A flight. Cameras considered are the Hasselblad 500 EL, the Maurer 246-1, the Hycon HG-491 and the Hycon HG-490.

2. ANALYSIS

2.1 Need for Support Photography - Shown in Table 1 are the Applications experiments requirements for support photography and attitude determination.

Table I - Experiments

Experiment	Support Photography Required	Attitude Determination Required
Group 1		
Metric Camera	No	Provided with Experiment
Multispectral Camera	No	Yes (0.5° 3σ)
IR Imager	Yes	No
IR Radiometer	Yes	Yes (0.1° 3σ)
IR Spectrometer	Yes	Yes (0.1° 3σ)
Multifrequency Microwave Radiometer	Yes	Yes (0.2° 3σ)
Group 2		
IR Temperature Sounding	Yes	Yes (1° 3σ)
Electrically Scanned Microwave Radiometer	Yes	Yes (1° 3σ)
UHF Sferics	Yes	Yes (2° 3σ)
Other		
Day/Night Camera	No	No
Dielectric Tape Camera	No	Maybe

The Applications Group 1 experiments are boresighted and operate simultaneously during daylight over the zone of interior. The photographs obtained by the metric and multispectral cameras are sufficient to meet the requirements for support photography. The metric camera has a stellar camera to provide attitude information.

The Group 2 experiments are also boresighted, and operate simultaneously. However, Group 2 operates continuously during the application days and thus cannot rely on Group 1 for support photography or attitude determination.

One approach to meeting these support photography and attitude requirements is to utilize a terrain camera to provide support photography and to rely on the spacecraft G&N system for attitude information.

An alternative approach is to meet the attitude determination requirements of Group 2 by utilizing a stellar attitude reference camera in conjunction with the terrain camera. The two cameras would provide both support photography and attitude determination.

The optimum camera for each of these alternative approaches will be selected.

2.2 Camera Capacity Requirements - Group 2 operates for a total of 46 hours during the mission and requires complete photographic coverage during all daylight hours. (The Day/Night Camera will provide support photography at night.) Assuming approximately 75° angular coverage ($1\frac{1}{2}$" focal length) and 10% overlap, the framing rate is approximately one per 42 seconds. The total number of frames required by the terrain camera for the 23 daylight hours will then be 2000. Assuming the same framing rate for the stellar camera during the 23 dark hours, the total number of frames required is 4000.

The expected attitude rates during local vertical maintenance are 0.02°/sec. A stellar framing rate of once per 42 seconds provides 0.84° deviation between frames; knowledge of the line of sight between frames is obtained assuming a constant drift rate. Thus attitude information can be obtained with much better accuracy than the maximum Group 2 requirement of 1° 3σ .

2.3 Camera Candidates - Shown in Table 2 are the features of each of the candidate cameras.

2.3.1 Hasselblad 500 EL - This camera is of proven quality and is to be used for the multispectral application; however, the present maximum film magazine capacity is 180 frames, thus requiring 11 film cassettes (10 film changes) to meet the 2000 frame requirement for the terrain camera and 22 cassettes (21 changes) for the stellar camera. Moreover, the camera has no reseau or data block capability. Supply and take up reels are not separable.

Table 2 - Camera Features

	Hassel-blad 500 EL	Maurer 246-1	Hycon HG-491	Hycon HG-490
Automatic film advance	Yes	Yes	Yes	Yes
Reseau grid	No	No	Yes	Yes
Automatic exposure control	No	Yes	Yes	Yes
Standard magazine capacity	180 frames	580 frames	2400 frames	2400 frames
Data block	No	Yes	Yes	Yes
Take-up/supply cassettes separable	No	No	Yes	Yes
Hermetically sealed case	No	No	Yes	Yes
<u>Alternate 1-Terrain Camera Only</u>				
Ascent Weight (lbs)				
Camera	4.25	7.5	17.	N/A
Film and Cassettes	35	12	3.5	N/A
	39.25	19.5	20.5	
Return weight (lbs)	35	12	3.5	
Film changes required (plus recovery operation)	10 + 1	3 + 1	0 + 1	N/A
<u>Alternate 2-Terrain Camera plus Stellar Camera</u>				
Ascent Weight (lbs)				
Cameras*	9	15	34	33
Film and Cassettes	43	39	10.5	10
	52	54	44.5	43
Return weight (lbs)	43	39	10.5	10
Film changes required (plus recovery operation)				
Terrain	10 + 1	3 + 1	0 + 1	0 + 1
Stellar	21 + 1	7 + 1	1 + 1**	1 + 1**

* includes weight of both the terrain and stellar cameras
**possible modification to larger cassette will enable no film changes for the stellar camera

2.3.2 Maurer 246-1 - The Maurer camera has been used on aircraft and on previous manned flights. Although difficulties were encountered in the space application, they are reported to have been resolved. The maximum standard capacity, however, is 580 frames, thus requiring 4 film cassettes (3 film changes) for the terrain camera, and 8 cassettes (7 film changes) for the stellar camera. No provision exists for a reseau grid or for separating the take up and supply cassettes.

2.3.3 Hycon HG 491 - The Hycon HG 491 has been developed for space applications and is designed to operate as a hermetically sealed unit with humidity conditioning. A hold down plate with a reseau is used and a data block incorporating a frame counter and gray scale is incorporated into the format. The magazine capacity is 2400 exposures and the takeup cassette is separable from the supply reel.

2.3.4 Hycon HG 490 - The Hycon HG 490 has also been developed for space applications and is designed to operate as a hermetically sealed unit with humidity conditioning. A stellar camera is incorporated into the same housing as the terrain camera and is designed to provide precise attitude determination. Magazine capacity is 2400 exposures and the take up and supply reels are separable, minimizing return weight and volume.

3. CONCLUSIONS AND RECOMMENDATIONS

Support photography and attitude reference are supplied for the Group 1 experiments by the metric and multispectral cameras. The Group 2 experiments require both support photography and attitude determination continuously during their operation cycles.

For alternate 1 operation mode in which the attitude information is derived from the spacecraft G&N system, the recommended camera is the Hycon HG 491. The factors that lead to this choice are as follows:

1. Reseau grid
2. Automatic exposure control
3. Magazine capacity 2400 exposures - no film reloads required
4. Data block
5. Take up and supply reels separable
6. Hermetically sealed case
7. Lowest return weight (3.5 lbs)

For alternate 2 operation mode in which the attitude information is derived from stellar photographs, the recommended camera is the Hycon HG 490. The determining factors are:

1. Reseau grid
2. Automatic exposure control
3. Magazine capacity 2400 exposures - no reloads required for terrain camera, one reload for the stellar camera; possible modification may eliminate the requirement for this reload operation

4. Data block
5. Take up and supply reels separable
6. Hermetically sealed case
7. Lowest return weight (10 lbs)
8. Internal alignment of terrain and stellar cameras provides the most precise attitude information

For baseline approach the alternate 1 mode of operation was used with the Hycon HG 491 camera.

PR-29-29

TRADE STUDY REPORT

EXPERIMENT S019 AND S020 FILM EXTRACTION

AAP/PIP EARLY APPLICATIONS

J
2C

CONTRACT NAS 8-21004

31 August 1967

Prepared by: ROY APPLEGATE

Approved by: DAVE PROCTER-GREGG

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1.0 INTRODUCTION

The purpose of this report is to analyze the feasibility of separating the film magazines from experiments S019 and S020 equipment canisters as a means of reducing re-entry weights and volumes on Flight 1A.

2.0 ANALYSIS

In the present design configuration for experiments S019 and S020, the spectrograph camera, film magazine and all mechanical supporting hardware are mounted into a single assembly. No provision has been made to extract the film from this assembly under flight conditions. In the S020 experiments, the spectrograph camera and film are an integral assembly; however, in the S019 experiment, the spectrograph camera and the film magazine are separate assemblies.

Some problems associated with in-flight disassembly of the experiment canisters are:

a. Loss of vacuum to the film magazine is undesirable until the film is ready to be developed.

b. Complexity of the existing hardware design precludes ease of disassembly.

c. In order to significantly reduce the return weight, some repackaging may be required so as to return only essential components.

At the present time, analysis are being made under contract to MSC Houston by the S019 and S020 hardware contractors to study the feasibility of film extraction. Preliminary indication from these studies suggest some difficulty with S019 due to its complexity. However, S020 does not appear to be so formidable a challenge. Anticipated size and weight reduction are as follows:

	Present Equip. Size -Weight	Proposed Re-entry Size -Weight
S020	6½ x 5 3/4 x 16(in) - 24 lbs-11 oz.	6 x 6 x 6(in) - 7 lbs.
S019	8 x 8 x 16 3/4(in) -43 lbs. (including bracket)	9 x 9 x 9(in) - 20 lbs.

A net re-entry reduction of approximately 0.4 ft^3 and 40 lbs. would be realized. Special tools (estimate 6 x 6 x 3 inches and 3 lbs.) required for film removal.

Reference is made to trade study Report No. PR-29-16 "CM Stowage Management". Allowable weight and volumes available in the CM for re-entry would indicate that the experiments as presently designed could be accommodated in the CM without difficulty. The anticipated size and weight reductions in the modified experiment return configuration is, of course, a significant reduction and as such is highly desirable. If the presently designed stowage location in the CM lower equipment bay is not available for Mission 1A, then greater emphasis would be placed on the desirability to expedite experiment re-design.

3.0 CONCLUSIONS

a. The experiment hardware in its present design configuration is not capable of in-flight film extraction.

b. Considerations of the weight and volume capacity of the CM for re-entry indicate that experiments S019 and S020 could be easily accommodated without the equipment modification.

c. Study contracts are being worked at the present time by the respective experiment contractors to study the film extraction feasibility. The anticipated re-entry volume and weight reduction is highly desirable. However, there is no indication that the required modifications and mandAtory requalification of these units would permit their use on the 1A early flight.

PR 29-30

TRADE STUDY REPORT

SCIENTIFIC EXPERIMENT MODIFICATIONS

AAP/PIP EARLY APPLICATIONS

CONTRACT NAS8-21004

31 AUGUST 1967

Prepared by: Roy Applegate

Approved by: D. Procter-Gregg

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1. INTRODUCTION

1.1 The purpose of this study is to specify the experiment modifications anticipated as a result of integrating the scientific experiment complement into the 1A Flight.

1.2 Objectives - The experiment integration activities have stressed the concept of minimum modifications to experiments. Some modifications were inevitable, however, primarily because the stowage and operating locations of the experiments must be changed from the original Block I design.

2. ANALYSIS

Table I of this trade study outlines all experiment modifications foreseen for Flight 1A. Anticipated command module modifications have been included to clarify impact of experiment integration.

TABLE I

Experiment	Experiment Modifications	Command Module Modifications
D008 Radiation Monitors	No experiment hardware design modifications required	1. Requires mounting provisions for 5 passive dosimeters and one active dosimeter. 2. Need power and data interface with active dosimeter.
D009 Simple Navigation	No experiment hardware design modifications required	1. Provide mounting position for sextant and stadimeter between sighting sequences.
D017 CO_2 Reduction	No experiment hardware design modifications required.	N/A

TABLE I (CONTINUED)

Experiment	Experiment Modifications	Command Module Modifications
T002 Manual Navigation Sightings	1. Possible modification or replacement of experiment cable assembly.	1. Requires interfaces with CM data system for "time-hack". 2. Provide stowage provision for re-entry. 3. Provide mounting position for sextant between sighting sequences.
T003 Aerosol Particle Analyzer	1. Remove velcro tape and provide other suitable mounting hardware.	1. Provide appropriate mounting interface for analyzer. 2. Provide stowage.
T004 Frog Otolith	No experiment hardware design modifications required.	N/A
S015 Zero-G Single Human Cells	1. Remove velcro tape and provide other suitable mounting hardware. 2. Possible modification or replacement of experiment cable assembly.	1. Provide power interface with experiment package. 2. Provide new stowage location if presently designed location is not available.
S016 Trapped Particle Asymmetry	1. Modify main emulsion package to provide an approximate 45° inclination of emulsion to airlock extension rod.	1. Provide stowage provision for re-entry.
S017 X-Ray Astronomy	1. Modify input circuitry to experiment tape recorder (part of S017 data package) to permit time-share recording with earth resources experiments. 2. Delete some functional capability in existing S017 data system (e.g., UHF transmitter).	1. Provide mounting provision in vicinity of IMU sextant for S017/T004 control unit. 2. Provide G&N PCM word, G&N start and 51.2KC clock to CM/carrier interface.

TABLE I (CONTINUED)

Experiment	Experiment Modifications	Command Module Modifications
S018 Micrometeorite Collection	No experiment hardware design modifications required.	1. Provide stowage provision for re-entry.
S019 UV Stellar Astronomy	1. Possible modification or replacement of experiment stowage bracket assembly. 2. Current study by hardware contractor to examine film extraction feasibility.	1. Provide stowage provision for re-entry.
S020 UV X-Ray Solar Photography	1. Possible modification or replacement of experiment data/power cable assembly. 2. Current study by hardware contractor to examine film extraction feasibility.	1. Provide stowage provision for re-entry.

Note: The anticipated modifications outlined in Table I are based on the current understanding of hardware design and command module configurations.

An understanding of the analysis that was made to determine experiment boost, stowage, re-entry and operation locations is essential to the understanding of these proposed modifications. Reference is made to trade study report no. PR26-31 "Experiment Locations."

3. CONCLUSIONS AND RECOMMENDATIONS

3.1 Experiment modifications outlined above represent the minimum hardware changes consistent with the Flight 1A integration requirements and experiment objectives.

3.2 The modifications are not extensive and can be accomplished within the alloted time.

PR-29-31

TRADE STUDY REPORT

SCIENTIFIC EXPERIMENT LOCATIONS

AAP/PIP EARLY APPLICATIONS

CONTRACT NAS 8-21004

31 August 1967

Prepared by: Roy Applegate

Approved by: D. Procter-Gregg

1.0 INTRODUCTION

1.1 The purpose of this study is to optimize the Flight 1A experiment locations with respect to boost, operation and re-entry periods.

1.2 Objectives - In the preparation of this study, consideration was given to boost and re-entry restrictions in the command module, experiment objectives, and current hardware design.

2.0 ANALYSIS

2.1 The following table lists the selected locations and some of the reasoning behind the selection.

Experiment Locations

Experiment	Boost or Stow	Use	Leave or Return
D008 Radiation Monitors	CM	CM	CM

Reason

1. Experiment objectives can only be met with installation in the CM. Weight is not restrictive ($\approx$ 5 lbs. total).

2. Both passive & active units must be returned, and the existing mounting provisions are not conducive to in-flight removal.

Experiment	Boost or Stow	Use	Leave or Return
D009 Simple Navigation	In Carrier	CM Window	In Carrier

Reason

1. Stowage and disposal in the carrier will reduce boost and re-entry weight of the CM.

2. Operation best conducted in the CM due to existing crew stations and calibrated view window.

Experiment	Boost or Stow	Use	Leave or Return
D017 CO_2 Reduction	Outside Carrier	Outside Carrier	Outside Carrier

Reason

1. Thermal constraints and requirements to vent product gasses dictates external location. Carrier truss satisfies this requirement and eliminates boost and re-entry weight of CM.

Experiment Locations table (continued)

Experiment	Boost or Stow	Use	Leave or Return
T002 Manual Navigation Sighting	In Carrier	CM Window	CM

Reason

1. Stowage in carrier to reduce boost weight of CM.

2. Operate in CM due to existing crew station and calibrated optical view window.

3. Re-entry in CM to satisfy requirement for return of sextant for post flight analysis.

T003 In-Flight Nephelometer	CM	CM	CM

Reason

1. Experiment objectives require operation in the CM.

2. Boost location was selected in the CM for convenience since the weight and volume is small.

3. Return in the CM is required as all data is contained within experiment.

T004 Frog Otolith Function	Outside Carrier	Outside Carrier	Outside Carrier

Reason

1. Experiment lends itself to external mounting, and experiment does not require return. The carrier truss best satisfies these requirements.

S015 Zero-G Single Human Cell	CM	CM	CM

Reason

1. "Tender loving care" and continuous crew support at regular intervals required for operation. These requirements not consistent with carrier location; therefore, dictating CM location.

Experiment Locations table (continued)

Experiment	Boost or Stow	Use	Leave or Return
S016 Trapped Particle Asymmetry	In Carrier	Carrier Airlock	CM

Reason

1. The carrier bulkhead scientific airlock will permit an unobstructed field of view, and an earth vertical orientation.

2. Since two scientific airlocks are scheduled for use in the carrier, the bulkhead airlock may be used exclusively by this experiment to satisfy requirements for long exposure.

3. Stowage in the carrier for boost will reduce CM boost weight, return in the CM is mandatory for postflight analysis.

S017 X-Ray Astronomy	Outside Carrier	Outside Carrier	Outside Carrier

Reason

1. External mounting required for X-ray sensor which is consistent with carrier truss.

2. Excessive weight does not restrict CM boost or re-entry requirements when equipment is confined to carrier.

S018 Micrometeorite Collection	In Carrier	Carrier Airlock	CM

Reason

1. Carrier scientific airlock permits relatively unobstructed field of view, and airlock is provided for other experiments.

2. Stowage in the carrier for boost will reduce CM boost weight, return in the CM is required for post-flight analysis.

3. "No contamination" requirement can be met by disabling RCS forward thrusters and restricting waste dumpage.

S019 UV Stellar Astronomy	In Carrier	Carrier Airlock	CM

Reason

1. Carrier airlock ideally suited to experiment operation.

2. Carrier boost location selected to reduce CM boost weight; return of the experiment in the CM required to satisfy post flight evaluation.

Experiment Locations table (continued)

Experiment	Boost or Stow	Use	Leave or Return
S020 UV X-Ray Solar Photography	In Carrier	Carrier Airlock	CM

Reason

1. Carrier airlock ideally suited to experiment operation.

2. Carrier boost location selected to reduce CM boost weight; return of the experiment in the CM required to satisfy post flight analysis.

NOTES:

1. Reference to trade study Report PR-26-32 "Scientific Airlock"; Analyses indicates the most practical location of the scientific airlock is in the carrier.

3.0 CONCLUSIONS AND RECOMMENDATIONS

1.1 The conclusions of this study are contained in the "reasons" column of the table above. It is felt that the locations selected satisfy all experiment objectives and provides a concept that can be easily satisfied without major changes to existing hardware.

PR 29-32

TRADE STUDY REPORT

SCIENTIFIC AIRLOCK STUDY

AAP/PIP EARLY APPLICATIONS

CONTRACT NAS8-21004

31 AUGUST 1967

Prepared by Roy Applegate

Approved by D. Procter-Gregg

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1. INTRODUCTION

The purpose of this study is to analyze the location and operation parameters for the scientific airlock and airlock experiments.

2. ANALYSIS

All major considerations required to make this analysis are shown in brief form in Table I. The table accomplishes the following:

a. Considers various advantages and disadvantages of locating the scientific airlock in the two possible locations: command module or carrier.

b. Considers the various advantages and disadvantages of operating the airlock experiments in each of the three possible operating modes:

   1) Operation from a command module scientific airlock.

   2) Locating the experiment in a carrier scientific airlock and operating remotely from the command module.

   3) Locating and operating the experiment from a carrier scientific airlock.

TABLE I
AIRLOCK LOCATION CONSIDERATIONS

	Airlock in CM	Airlock in Carrier-Operation from CM	Airlock in Carrier-Operate in Carrier
Airlock	1. Scientific airlock needs redesign for single piece door. 2. Ablative plug is single malfunction mode for CM. 3. No M&R Contractor. 4. More than one scientific airlock required simultaneously. 5. No adaptive hardware available. 6. No experiment modifications required.	1. Can accommodate existing design scientific airlock. 2. No problem with ablative plug, as is not used. 3. No limit to number of airlocks. 4. Adaptive hardware incorporated in basic design. 5. Experiment modifications may be required for remote control. 6. Airlock modification to permit remote control impractical.	1. Can accommodate existing design scientific airlock. 2. No problem with ablative plug, as it is not required. 3. More than one airlock may be installed. 4. Adaptive hardware incorporated in basic design. 5. No experiment modifications required. 6. Needs crew station for experiment operation and attitude control.
S016 Trapped Particle Asymmetry	1. Cannot fly simple earth vertical attitude in SAA. 2. Experiment requires no material "ahead" of collection device. 3. Must time share with other airlock experiments.	N/A (only deployment and retrieval required).	1. By placing in pressure bulkhead parallel to long. axis, can fly earth vertical position. 2. Permits unobstructed field of view. 3. Capability for more than one airlock permits long uninterruped exposure periods.

TABLE I (CONTINUED)

	Airlock in CM	Airlock in Carrier-Operate from CM	Airlock in Carrier-Operate in Carrier
S018 Micrometeorite Collection	1. Requires RCS off during exposure period 2. Time share problem with other airlock experiments.	N/A (only deployment and retrieval required).	1. Requires RCS off during exposure periods. 2. Compatible with other airlock experiments when S016 is assigned to a separate airlock.
S019 UV Stellar Photography	1. Can be run from existing crew station.	1. Remoting of experiment not practical as experiment has manual sighting, shutter, film advance, focus and vacuum control.	1. Requires new crew station in carrier.
S020 UV X-Ray Solar Photography	1. Can be run from existing crew station. 2. Cabling not in, in Block II.	1. Remoting of experiment not practical as experiment has manual framing and exposure. 2. Sighting optics inside experiment.	1. Requires new crew station in carrier. 2. Cabling incorporated in basic carrier design. 3. Reduces data requirements on CM.

3. CONCLUSIONS

3.1 Airlock Location - It is recommended that the scientific airlock be located in the carrier for the following reasons:

3.1.1 The current scientific airlock hardware design presents a single malfunction mode (associated with the ablative plug) which is unsatisfactory for use in the CM from a crew safety standpoint. This same airlock, however, could be utilized in the carrier without modification since the ablative plug problem does not exist. All airlock experiments are compatible with the existing scientific airlock design without modification.

3.1.2 Due to the long exposure periods received by experiment S016, a single scientific airlock is not compatible with experiment demands. The carrier will permit more than one airlock by incorporation of these requirements in its basic design.

3.2 Scientific Airlock Experiment Operating Locations

3.2.1 Experiment S016 - A scientific airlock in the carrier bulkhead is ideal for this experiment. 1) It provides an unobstructed field of view. 2) It permits an earth vertical pointing (consistent with all earth mapping experiments), which, programmed with a roll maneuver during passes over the SAA will satisfy the demanding pointing requirements of this experiment. 3) A separate airlock for the exclusive use of S016 will permit the long exposure periods required to satisfy experiment objectives.

3.2.2 Experiment S018 - Operation from the carrier scientific airlock is recommended. 1) Analysis presented on airlock location indicates availability exclusive to carrier. 2) Carrier scientific airlock satisfies all experiment objectives for field of view, restriction of contamination, exposure time requirements.

3.2.3 Experiment S019 - Operation of this experiment from the carrier airlock using a combination of manual experiment command, and remote control of pointing and stabilization is recommended. A completely remote operation is impractical due to the number of manual controls on the experiment and airlock. On the other hand complete control from the carrier is impractical due to

3.2.3 Experiment S019 (continued)
the difficulty in locating an attitude control station in the carrier. 2) By boresighting the experiment with the IMU sextant, all attitude control functions can be provided remotely from the CM. A crew station in the carrier would be required for initial boresighting, shutter, film advance, focus and vacuum control.

3.2.4 Experiment S020 - Operation of this experiment from the carrier airlock (same airlock as S019) using a combination of manual experiment control, and remote control of pointing and stabilization is recommended. 1) As explained for S019, completely remote control, or completely carrier local control is impractical. 2) By providing a sun sensor on the carrier that is common boresighted with the experiment package, a reference pointing method can be remoted to the CM. The sun sensor would be provided as part of the carrier subsystem. All attitude control function would then be performed remotely from the CM. A crew station in the carrier would be required for initial target acquisition, manual framing and exposure control.

PR-29-33

STUDY REPORT

DISPLAY AND CONTROL STUDIES

AAP/PIP EARLY APPLICATIONS

CONTRACT NAS 8-21004

31 August 1967

Prepared By: Donald D. Higley

Approved By: [signature]

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1.0 INTRODUCTION

1.1 Purpose - The purpose of this report is to investigate methods that could be used to satisfy the display and control requirements and to propose a system for the 1A Program.

1.2 Objectives - The objective of this study is to establish a baseline design for the display and control system.

2.0 SUMMARY

This report defines the requirements and constraints imposed on the design of a display and control system for the 1A mission. Each supporting subsystem and experiment is reviewed and the requirements of each are defined. The two methods that could be used in the design are defined as direct and indirect. These methods are discussed and the advantages and disadvantages of each method are outlined. Theproblem of establishing control status is discussed in conjunction with logic systems. Several alternate design approaches are investigated and the results are summarized in Table 1. It was found that a system employing both logic circuits and time sharing would be required for the 1A mission. The need for this system was predicted by the interface pin constraint. The main factors involved in a panel layout are defined as panel area and functional ease. Two methods that could be used in a panel design are discussed and a preliminary panel layout is described.

3.0 DISPLAY AND CONTROL SYSTEM FOR 1A MISSION

3.1 Background - The display and control system for the 1A mission will consist of a control panel in the CM and the necessary equipment in the carrier to receive and transmit signals from the experiments and supporting subsystems. The constraints to be described in the following paragraphs dictate that only that capability required for mission success should be considered in the design.

Previous studies and preliminary information concerning the 1A experiments indicate that the primary functions of the display and control system will be to initiate control signals. Closely related to this function is the problem of providing the astronaut with control system status. In addition, some capability for indicating system status must be included in the design.

3.1 (continued)

This includes both that information required to properly direct system operation (end of tape signal) and information that is directly related to crew safety (caution signals).

Constant display of analog signals has been discouraged unless the information is essential for mission success. However, it is expected that some capability for monitoring analog information will be required. Some of the experiments will require components peculiar to the experiments. These could be potentiometers, meters or other equipment necessary for proper operation of the experiment. In order to have some basis for a design, the various methods for accomplishing the above functions must be investigated in light of the requirements and constraints. Therefore, in the following paragraphs, methods and design approaches for initiating commands, presenting status information and displaying analog signals will be analyzed. The results of these analysis will then be used to formulate a preliminary design for the display and control system.

3.2 Requirements and Constraints

3.2.1 Mission Requirements - The scientific experiments included in the 1A mission will, for the most part, be performed under the direction of the Apollo astronauts. In order to provide the capability for this direction, a system of displays and controls will be required in the Apollo command module. Any proposed system must naturally satisfy the requirements imposed by the experiments and supporting subsystems. In addition, the system must be designed under certain limiting program constraints. These constraints involve both the mission planning and the physical limitations of the Apollo vehicle.

3.2.2 Constraints - Probably the most demanding constraint will be the allocated program time. The total period is expected to be approximately 13 months. This means that the design effort must be completed in not more than 4 to 5 months. Therefore, it is imperative that proven designs and qualified hardware be used throughout. The feasibility of the entire program is based on

3.2.2 (continued)

compatibility with the Apollo system. Extensive modifications could not be accomplished in the allotted program time. For this reason, the display and control system must be designed around the following physical constraints.

1. The total capability of the electrical interface consists of 65 pins for signals and 8 for shields, these are distributed between two connectors. However, it must be pointed out that in the present configuration only 41 pins are available, the balance being used for the SLA pyro circuits.

2. The total volume available in the CM for an additional display and control panel is limited. Preliminary information indicates that the panel area should not be larger than 240 in^2. (20 x 12 inches). The depth should not be greater than six inches.

3. The command module is severely limited in the amount of additional weight that can be accommodated during the boost phase. Therefore, considerations must be given to limiting added weight by carrying the display panel in the carrier during boost.

4. The carrier weight has been limited to a total of 5000 pounds. A large portion of this total will be allocated to battery weight, which in turn reflects the total power requirements of all systems. Therefore, it follows that power required must be defined as a limiting constraint.

3.2.3 Subsystem Requirements - The display and control requirements for the supporting subsystems are summarized as follows:

3.2.3.1 <u>Electrical Power System</u>

(1) Main Power - On/Off
(2) EMI Power - On/Off

3.2.3.2 <u>Thermal Control System</u>

(1) Back-up Pump-on
(2) Low Pressure Indicator

3.2.3.3. Data Management System

(1) S-Band Input, 1,2,3

(2) X-Mitter No. 3 - On/Off

(3) Recorder No. 1 - Playback/Stop

(4) Recorder No. 2 - Playback/Stop

(5) End of Tape - No. 1

(6) End of Tape - No. 2

3.2.3.4 Display and Control System

(1) Circuit Breaker (On Panel)

(2) Lamp Test (On Panel)

(3) Brightness Control -(On Panel)

3.2.4 Equipment Requirements - The display and control requirements are summarized in the following paragraphs. Experiments either not requiring display and control or containing a system which is operated in the carrier are not considered in the paragraphs.

3.2.4.1 Frog Otolith/X-Ray Astronomy

These experiments are furnished together and have a developed display and control panel. This system will be used for the 1A mission. The requirements are then, (1) capability to transmit data to and from the carrier and (2) 28 VDC power for the display panel.

3.2.4.2 CO_2 Reduction

Experiment Control - On/Off

Experiment Status

3.2.4.3 UHF Sferics

Power Control - On/Off

Beam Select No. 1/No. 2

Event Marker (Momentary-On)

3.2.4.4 Passive Microwave Radiometer

Experiment Control - On/Off

Experiment Status

3.2.4.5 IR Radiometer/Spectrometer

Standby/Off/Operate

Experiment Status

3.2.4.6 IR - Imager

Standby/Off/Operate

Experiment Status

3.2.4.7 Experiment Support Camera

Operate Manual/Off/Operate-Auto.

Frame Counter

3.2.4.8 Metric Cameras

Operate Manual/Off/Operate-Auto.

Frame Counter

3.2.4.9 Multispectral Cameras

Operate Manual/Off/Operate-Auto.

Frame Counter

3.2.4.10 Electro-Scan Microwave Radiometer

Power Control - On/Off

Scan Control - On/Off

Experiment Status

3.2.4.11 IR - Temperature Sounding

Standby/Off/Operate

Mode - Calibration/Long Period

Status

3.2.4.12 Dielectric Camera

Standby/Off/Operate

Mode - Record/Playback

Status

3.2.4.13 Day/Night Camera

Standby/Off/Operate

Mode - Auto/Manual

Spectrum Select (4)

Exposure Adjustment

Film Remaining (Meter Indication)

3.3 Display and Control Methods - The methods that may be used to accomplish the display and control function can be described as either direct or indirect. These methods are described in the following paragraphs.

3.3.1 Direct Method - The direct method consists of using individual indicators and control switches on the panel, then hardwiring each across the interface. The advantages of this method are: simplicity, reliability and functional ease. The disadvantages are: number of interface pins required, panel area required and the lack of system flexibility.

3.3.2 Indirect Method - The indirect method employs logic systems for initiating commands and/or indicating status. The main advantage of these systems is that many signals may be transmitted over a small number of lines. For example: given n logic lines, 2^n control signals may be sent across the interface. A logic system for status signals could be devised using only three lines. One line would be used for a clock signal; another would carry status information and the third would be the reset signal. Block diagrams of typical systems are shown in Figures 1 and 2. These methods might appear attractive on the surface, but several disadvantages are apparent. The most obvious, is that they are much more complex than the direct method. It follows that they would be most costly. These two disadvantages could have

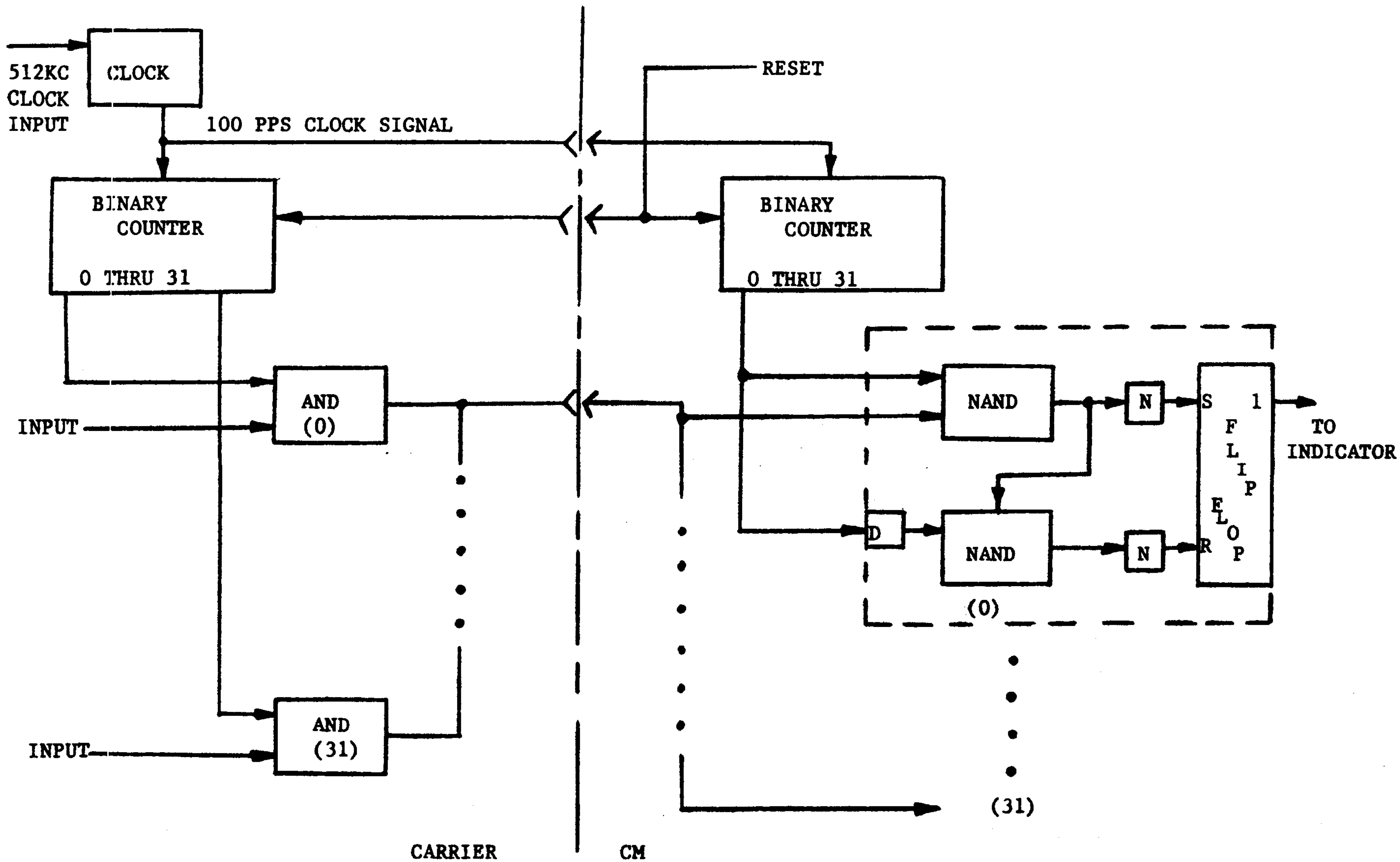

FIGURE 1

STATUS MULTIPLEX SYSTEM

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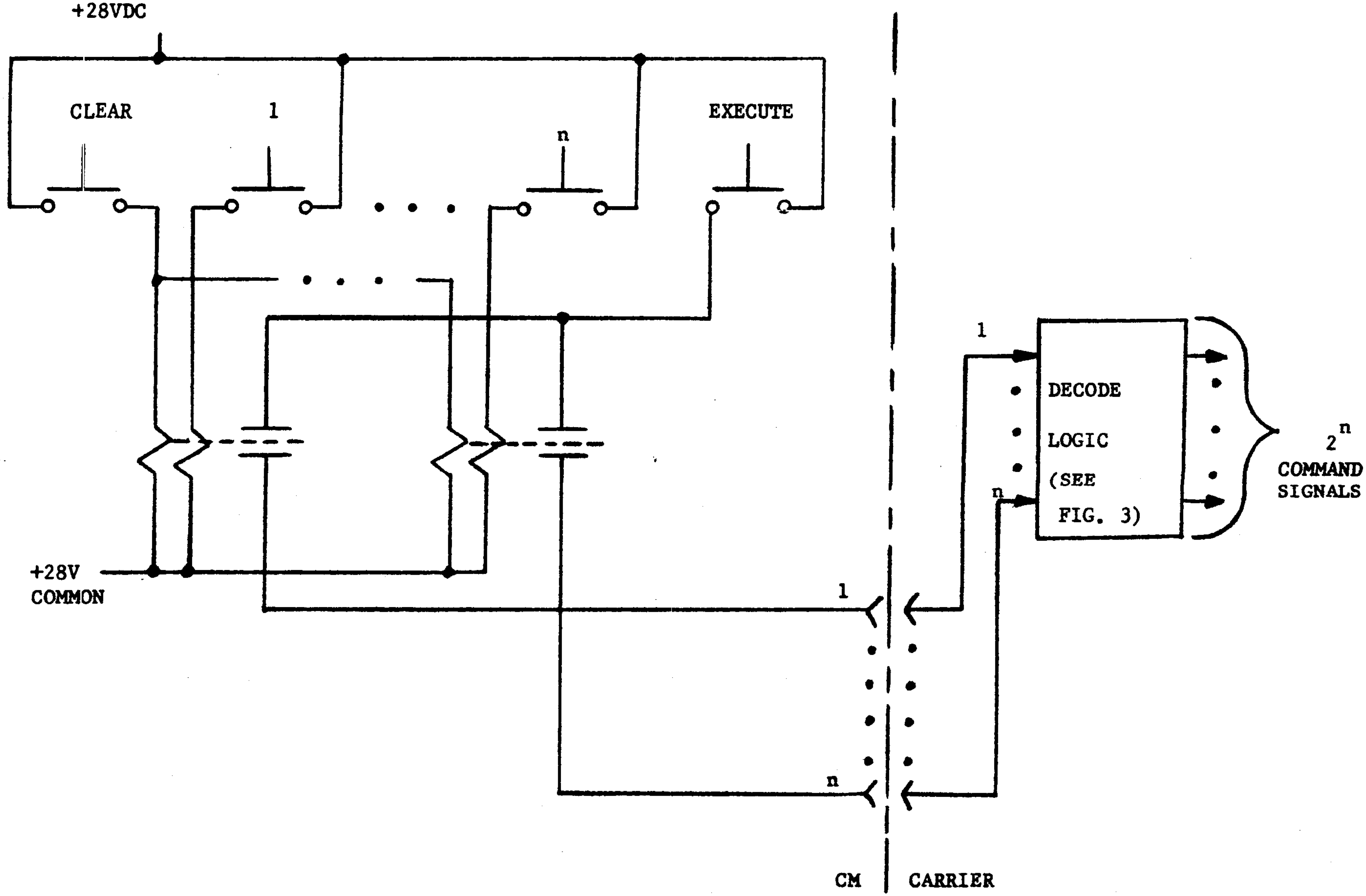


FIGURE 2

COMMAND CONTROL LOGIC

3.3.2 (continued)

serious impact on program schedules and total cost. The problem of establishing control system status is an additional disadvantage.

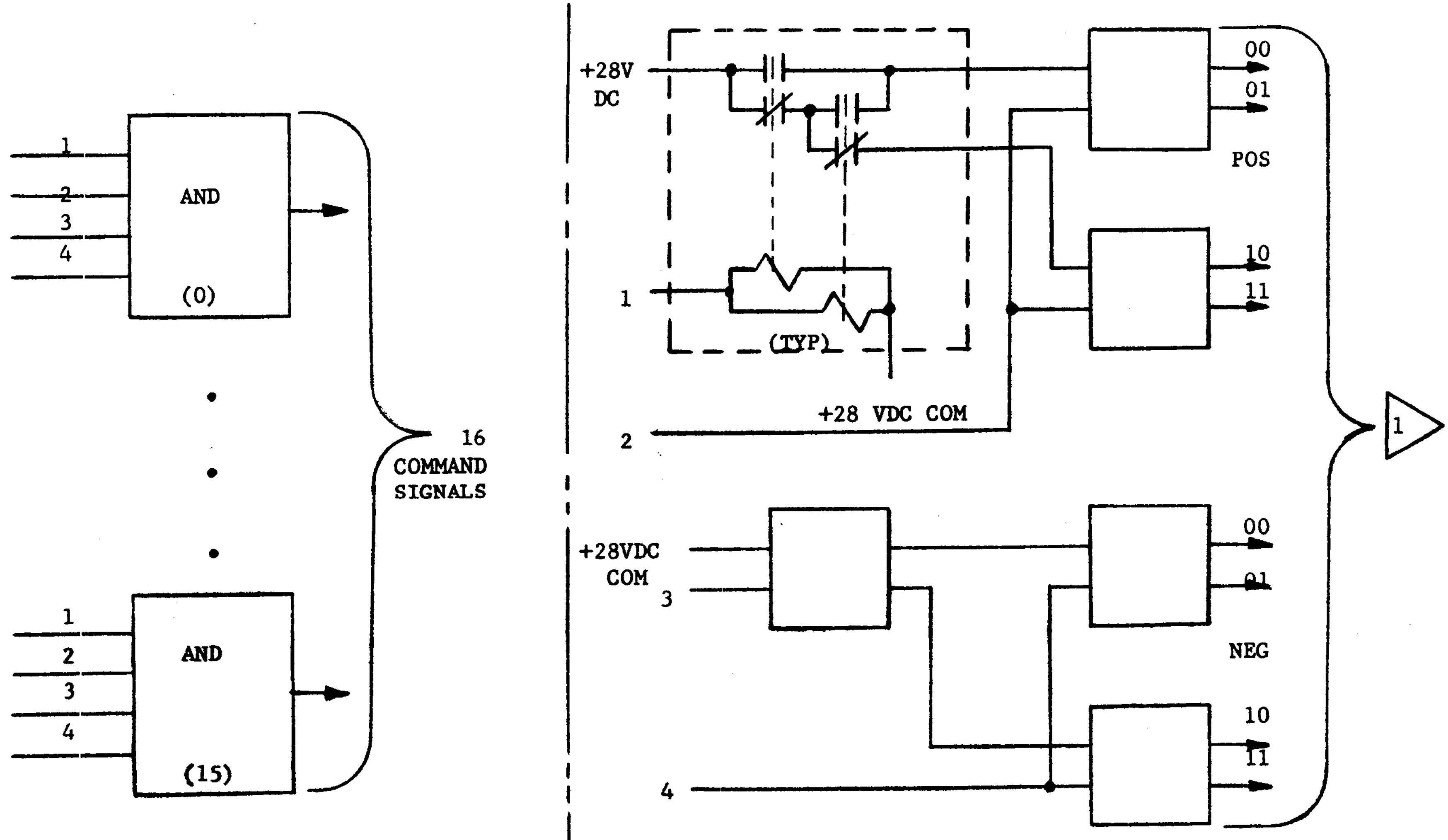
3.3.2.1 Control System Status - Assuming that it is necessary to employ a control logic system, then some method of describing the status of the control system must be included in the design. In the direct method a switch may be used to describe status. This situation, however, does not exist in the case of control logic systems. The coded signal is generated only momentarily via a keyboard or from individual momentary action switches. The coded signal is decoded and used to set latching type relays. Typical decoding currents are shown in Figure 3. The problem is then, once the control signal is sent over the logic lines, an indicator must be provided to tell the operator the state of the system (whether it is on or off). So by solving one problem, another one was created. The status indication may be devised in one of several ways, these are listed as follows:

1. Time multiplex status signals as described in paragraph 3.3.2.

2. Generate status signals from momentary switch contacts. (Each control signal would be generated from momentary switches).

3. Hardwire status signals across the interface to status indicators on the panel.

4. Periodically interrogate status by using the logic system. In this method only one or two lines are



SOLID STATE LOGIC

1 THE BINARY COMBINATION OF THE 4 POS AND 4 NEG SIGNALS WILL RESULT IN 16 COMMAND SIGNALS

RELAY LOGIC

DECODE LOGIC
FIGURE 3

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3.3.2.1 (continued)

4. (continued)

hardwired to the panel. A number of status signals, however, can be "called up" for display on the panel.

The third method is usually impractical since the reason for the control logic was to conserve interface pins. In this case, however, it may be advise-able as will be outlined in the following paragraphs.

3.3.3 Summary of Advantages and Disadvantages - The advantages and disadvantages of the two methods may be summarized as follows:

3.3.3.1 Direct Method

3.3.3.1.1 Advantages

1. Lower cost, when compared to the indirect method.

2. Higher reliability, since all functions are hardwired.

3. Relatively simple circuits.

4. Functional ease.

3.3.3.1.2 Disadvantages

1. Requires more interface pins.

2. Method is not flexible, new signals cannot be easily added.

3. Requires more panel area.

3.3.3.2 Indirect Method

3.3.3.2.1 Advantages

1. Many signals may be transmitted over a few lines.

2. System is highly flexible (if keyboard is used).

3.3.3.2.2 Disadvantages

1. High cost, compared to direct method.

2. Complex circuits.

3. Use of control logic creates problem of status indications.

3.4 Possible Design Approaches to Meet the 1A Requirements

3.4.1 Design Criteria - Before discussing the possible solutions to the 1A requirements, certain assumptions, facts and criteria will be established.

3.4.1.1 Location of Crew Station - The location of the crew station for operating the display and control system will be within the command module. The problem of course, would be simplified if it was assumed that operation occurred in the carrier. However, the total system philosophy is based on the ability of the crew to control the majority of experiments from the CM.

3.4.1.2 Requirements for (X-Ray Astronomy/Frog Otolith - The S-017/T004 experiments have their controls and displays in an experiment furnished control panel. The requirement in this case, is to provide the necessary electrical interface.

3.4.1.3 Hardwired Requirements - Certain controls and displays have been designated as hardwired functions regardless of what method is used in the final design.

3.4.1.3 (continued)

These are tabulated as follows:

1. Main power on/off.
2. EMI Power on/off.
3. TCS back-up pump-on.
4. Low Δ pressure indication.
5. Caution signals (4).
6. Up-data signals (4).
7. Panel DC power (2).

In addition, a minimum of 29 lines will be required from the S-017/T004 experiments when the S-017 experiment is in operation.

3.4.1.4 Timing Sharing S-017 Lines - It is assumed that since the S-017 operates only when all other experiments are off, that the lines from the CM to carrier for this system may be time shared with the standard applications.

3.4.1.5 Interface Pin Utilization - In this present configuration, only 41 pins would be available at the CM/Carrier interface. This number is not sufficient to support a control panel with only the S-017 experiment. Therefore, it must be assumed that the maximum interface capability will be made available after SLA separation. This will be accomplished by mating the D & C System, after the PYRO circuits are fired.

3.4.2 Design Approach Number 1 (Direct Method)- Based on the current requirements, it appears that the direct approach could be used as far a re-

3.4.2 (continued)

quired panel area is concerned. The requirements for interface pins are outlined in Table 1. The results indicate that 97 interface pins would be required. Therefore, the direct method cannot be used for all requirements.

3.4.3 Design Approach Number 2 - The next approach is to assume all control signals are transmitted via a logic system and that status signals are hardwired to indicators on the panel. In this method, complementary signals are indicated by one flag or light. For example if a function is "on", then the indicator is energized. If it is "off", the indicator is de-energized. The results in Table 1 show that 76 pins would be required across the interface. This approach, again would not be acceptable.

3.4.4 Design Approach Number 3 - This approach is basically the same as Number 2 except that 20 of the lines for experiment S-017 are time shared. This then allows some of the status indicators and display functions for the standard application to be hardwired with no additional penalty as far as interface pins are concerned. The results indicate that this method would require 62 interface pins. Again, this approach would not be satisfactory.

3.4.5 Design Approach Number 4 - This method is the same as Number 3 with the additional feature of a status multiplex system. This approach would require 45 interface pins. The pin allocation would be as follows:

Requirement	Pins Required
Logic Control	7
Status Multiplex	3
S-017/T004	29
Subsystem	6
Total	45 pins

The approach would provide more than enough capability to satisfy the 1A requirements. In

3.4.5 (continued)

fact, 71 spare control and 12 spare status channels would be available for future requirements. Some of this spare control capability would be used for "calling-up" and displaying analog information.

It should be pointed out that the selection of a 7 line logic system was made because a 6 line system would result in only 7 spare channels. Therefore, the selection could be termed somewhat arbitrary. If it is found that 7 "spares" are adequate or if the requirements are decreased, then by all means a 6 line system should be used, since a 7 line system is more than twice the complexity of a 6 line system.

3.4.6 Other Methods - Several other alternate solutions were considered, but will not be included in the study. The first concerns the method of establishing status. This could be done through the use of momentary switches, merely by using two contacts to drive a latching type relay. The output of the relay would then set the status indicator. The method would then require no signals across the interface. This approach, while attractive, was not considered because it is really not a status indication, being rather an indication of what has momentarily occurred in the panel.

Another alternate that might appear obvious is that of time sharing the capability of several experiments. This approach, however, is not possible since the latest time lines require that all Standard Applications Experiments be active at the same time.

3.4.7 Summary of Results - Based on the results tabulated in Table 1, it appears that the solution must be a system similar to that described in paragraph 3.4.5. This is the only selection that can be made in the face of the interface pin constraint.

TABLE 1

SUMMARY OF DESIGN APPROACH DATA

System	Requirements	Direct	Logic Only		Logic + Time Share			Logic + Time Share + Multiplexer			
		Pins Req'd.	Pins Req'd.	Logic Signals	Pins Req'd.	Time Shared	Logic Signals	Pins Req'd.	Time Shared	Mult. Signals	Logic Signals
Support-ing Sub-systems	Main Pwr-On/Off	2	2		2			2			
	EMI Pwr-On/Off	2	2		2			2			
	Rec. No. 1 - Play/Stop	2	1	2	1		2			1	2
	Rec. No. 2 - Play/Stop	2	1	2	1		2			1	2
	End Tape 1	1	1		1					1	
	End Tape 2	1	1		1					1	
	S-Band Input 1, 2, 3	3	3	3	3		3			3	3
	Xmtr. No. 3 - On/Off	1	1	2	1		2			1	2
	Pump-On	1	1		1			1			
	P Indicator	1	1		1			1			
S-017/ T004	Control Sig.	10		10			10				10
	H.W. Control Sig.	3	3		3			3			
	Display Signal	18	18		18			18			
	Data Signal	8	8		8			8			
CO_2 Red-uction	Exp. On/Off	1		2		1			1		
	Status	1	1			1			1		
UHF Sferics	Pwr-On/Off	1	1	2		1			1		
	Beam-No. 1/ No. 2	1	1	2		1			1		
	Marker	1		1		1			1		
Passive Microwave	Exp. On/Off	1	1	2		1			1		
	Exp. Status	1	1			1			1		

TABLE 1

SUMMARY OF DESIGN APPROACH DATA

System	Requirements	Direct	Logic Only		Logic + Time Share			Logic + Time Share + Multiplexer			
		Pins Req'd.	Pins Req'd.	Logic Signals	Pins Req'd.	Time Shared	Logic Signals	Pins Req'd.	Time Shared	Mult. Signals	Logic Signals
IR Radio/ Spec.	Stby/Off/Oper.	2	1	3		2			2		
	Status	1	1			1			1		
IR Imager	Stby/Off/Oper.	2	1	3		2			2		
	Status	1	1			1			1		
Support Camera	Off/Operate	2		3		2			2		
	Manual/Auto	0									
	Frame Count	1	1			1			1		
Metric Camera	Off/Operate	2		3			3				3
	Manual/Auto	0									
	Frame Count	1	1			1			1		
Multi-spectral Camera	Off/Operate	2		3			3				3
	Manual/Operate	0									
	Frame Count	1	1			1			1		
Electro-Scan Microwave	Pwr On/Off	1	1	2	1		2			1	2
	Scan On/Off	1	1	2	1		2			1	2
	Status	1	1			1			1		
IR Temp Sounding	Stby/Off/Oper.	2	1	3	1		3			1	3
	Mode-Cal/L.P.	1	1	2	1		2			1	2
	Status	1	1		1					1	
Dielec-tric Camera	Stby/Off/Oper.	3	1	4	1		4			1	4
	Mode-Rec./Play	0									
	Status	1	1		1					1	

TABLE 1

SUMMARY OF DESIGN APPROACH DATA

System	Requirements	Direct	Logic Only		Logic + Time Share			Logic + Time Share + Multiplexer			
		Pins Req'd.	Pins Req'd.	Logic Signals	Pins Req'd.	Time Shared	Logic Signals	Pins Req'd.	Time Shared	Mult. Signals	Logic Signals
Day/ Night Camera	Stby/Off/Oper.	3	1	4	1		4			1	4
	Auto/Manual	0									
	Spectrum Select	4	4	4	4		4			4	4
	Exposure Adj.	1	1			1			1		
	Film Remaining	1									
	TOTALS	97	69	64	55	20	56	35	20	20	56
	Summary of Pins Required	97	69 + 7 Logic 76 Total		55 + 7 Logic 62 Total			35 + 7 Logic 3 Multi 45 Total			

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3.4.7 (continued)

The selected system would require the following interface pin allocation:

Function	Pins Required
Power	2
Up-Data Link	4
Caution	4
S-017/T004	29
Subsystem	8
Control Logic	7
Status Multiplex	3
Call-up Lines	2
Total	59

This total requirement would then leave 6 spare pins for future requirements.

3.5 Proposed Display and Control System

3.5.1 System Description - The display and control system proposed for the 1A mission will be similar to that outlined in paragraph 3.4.5. The system, as shown in Figure 4, will contain the following major components:

1. Display panel in the CM

2. Experiment furnished display unit in the CM

3. Decoder system in the carrier

4. Status multiplex system (part in the carrier, and part in the CM)

5. Analog call-up system in carrier (call-up capability is provided by logic system)

6. Control distribution system in carrier.

3.5.2 Panel Layout - The two main considerations in developing a panel layout will be panel size and functional capability. Functional capability concerns the human engineering aspects of system operation and component layout.

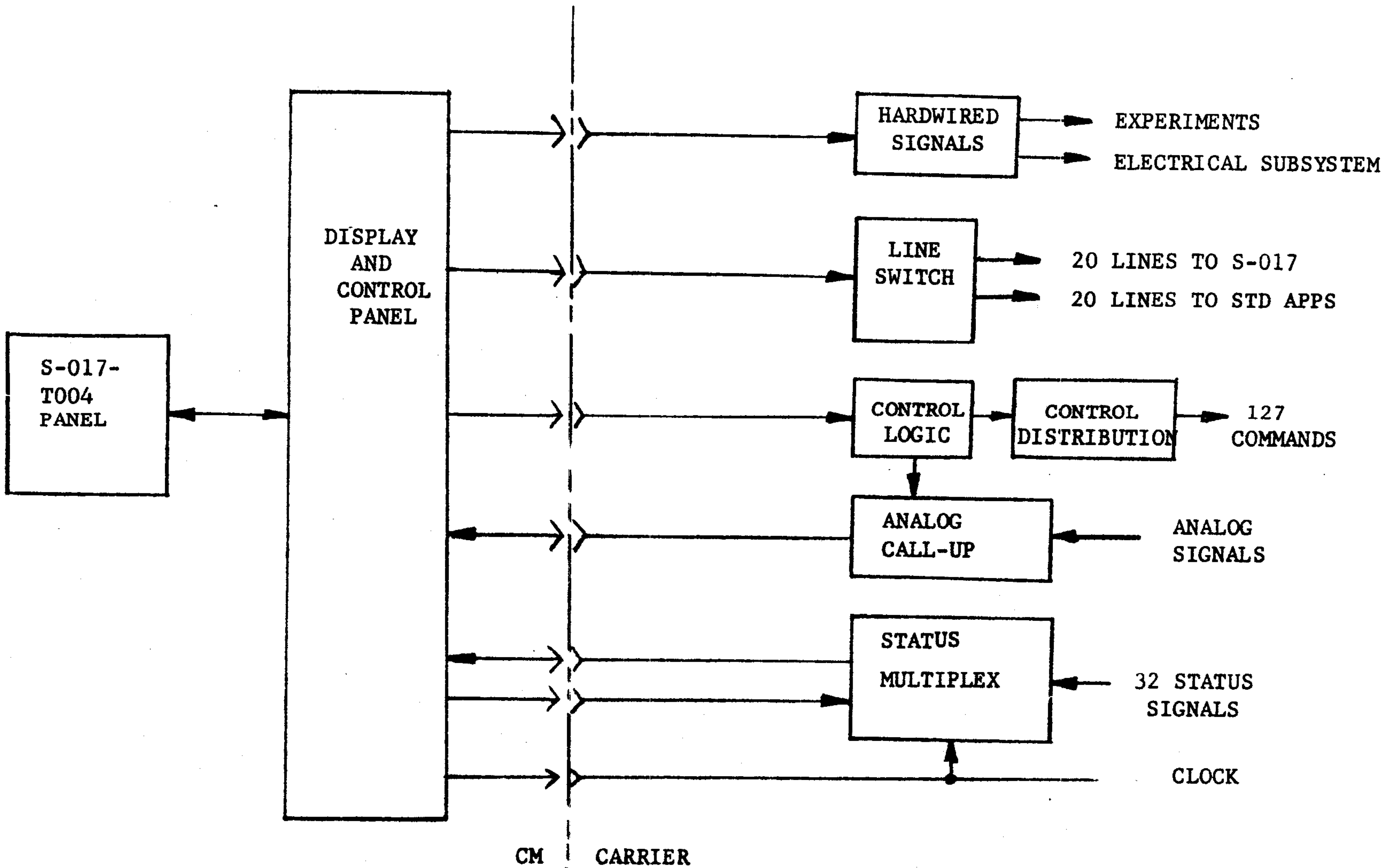


FIGURE 4

BLOCK DIAGRAM - DISPLAY AND CONTROL SYSTEM

3.5.2 (continued)

These two factors are in turn related directly to the method selected to initiate command signals, since this is the primary function of the display and control system.

Control signals may be initiated either from a keyboard or from individual momentary action switches. The keyboard approach results in a panel with minimum area and also in a panel with the poorest human engineering. The use of individual switches, on the other hand, results in a panel with maximum area, but is the most favorable from the human engineering standpoint.

3.5.2.1 Keyboard Method - In this method all logic lines are represented by individual push button switches. The procedure for sending a command to the carrier is to enter the code on the keyboard and then execute the command. The result of this action is then displayed on a status indicator. This method has several disadvantages:

1. The operator must have access to the required code

2. The probability for error is obviously higher than the other method.

The advantages of this method would be:

1. Less panel area required

2. The complete system capability would be contained in several push button switches. This factor would allow a high degree of flexibility.

3.5.2.2 Individual Switch Method - This method would provide individual switches for generating command signals. These switches would be 3 position, center

3.5.2.2 (continued)

off and momentary action in two positions. A typical cycle for this method would be as follows:

1. Select desired switch

2. Initiate command by moving switch to desired position, hold position momentary (until status indicator confirms signal is executed)

3. Release switch.

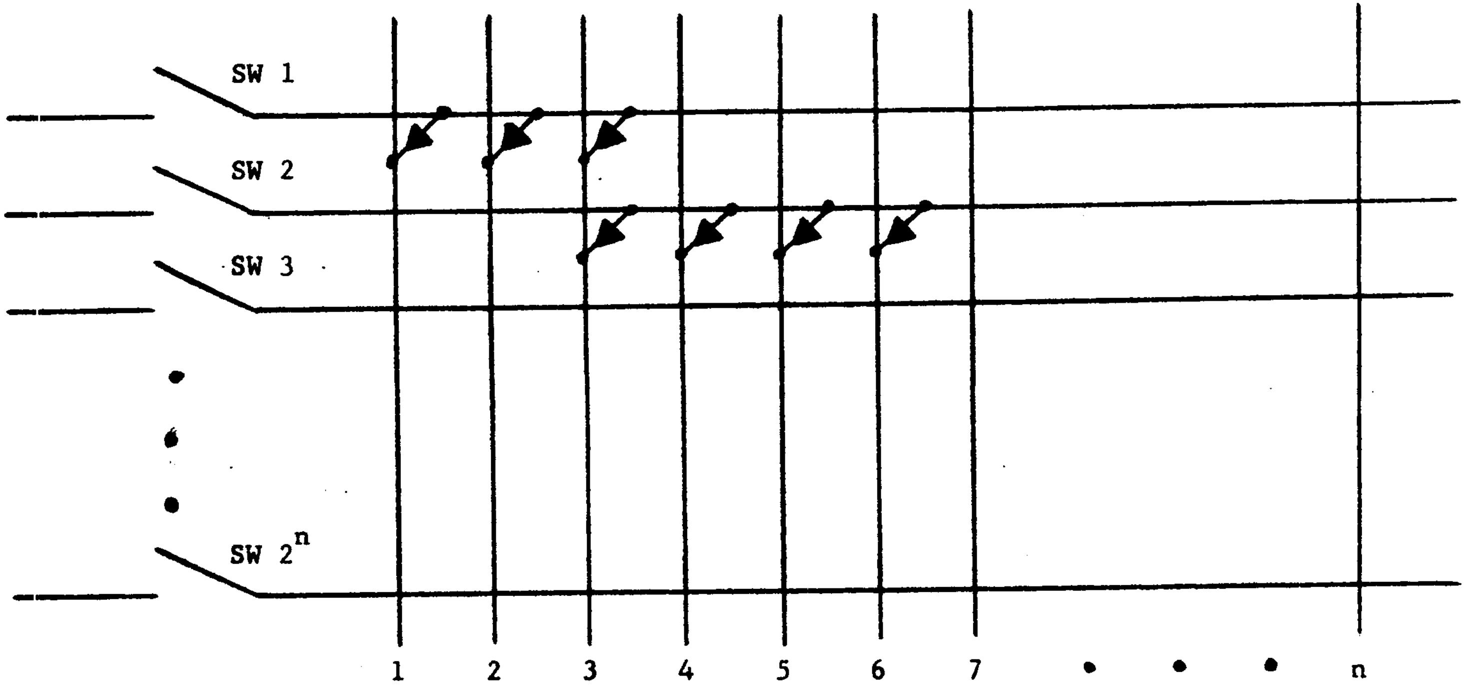
In this method, the signal from the switch is actually encoded over the logic lines. A typical diode encoder is shown in Figure 5.

3.5.2.3 Layout Proposed for 1A Mission - The layout selected for the 1A mission incorporates parts of both methods described above. Individual switches will in general, be used to initiate primary functions such as "operate" and "off", while the keyboard will be used for secondary functions such as "standby". This approach provides a system that is functional as well as flexible. A preliminary mockup of such a system is shown in Figure 6. This area of this particular layout is approximately 11 x 19 inches.

3.5.3 Additional System Features - The proposed system will incorporate all required experiment peculiar equipment such as a potentiometer for exposure control and film counters for the camera experiments. In addition, the following features will be included in the design.

1. Analog call-up system

2. Caution and Warning capability



EXAMPLE: CODE FOR SW 1 IS 1110000···n

CODE FOR SW 2 IS 0011110···n

FIGURE 5

DIODE ENCODER

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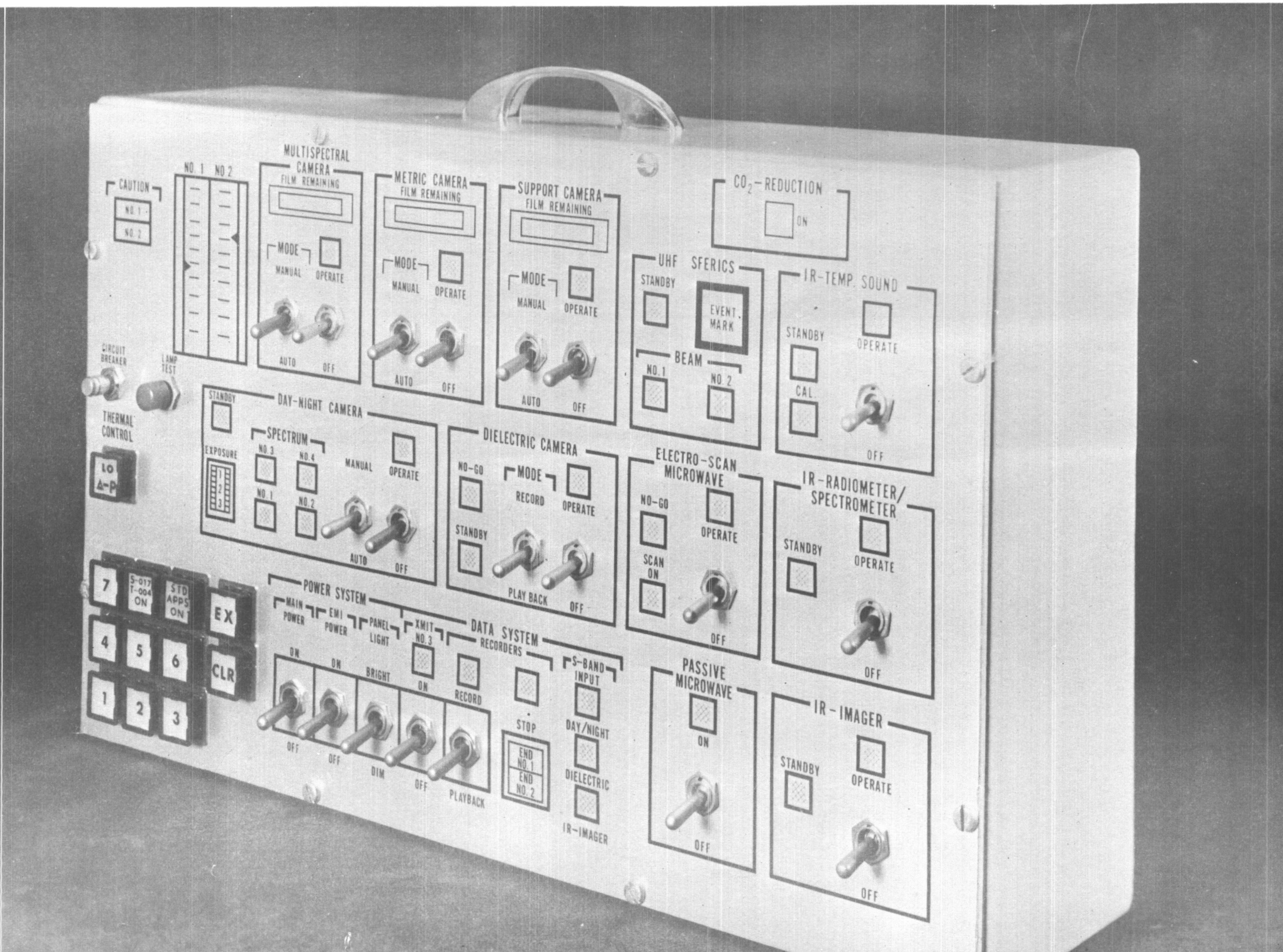


FIGURE 6

PRELIMINARY MOCKUP OF CONTROL PANEL

DA042802

3.5.3 (continued)

3. Up-data link capability

4. Status Multiplex reset

5. Capability for switching from S-017/T004 to Standard Applications

3.5.3.1 Analog Call-up System - This system will provide the capability for displaying a number of analog signals on a dual movement meter. When an analog display is required, the operator will select the proper code, enter it on the keyboard and execute the command. This command will energize the proper circuits and place the analog signal on data lines terminating at the meter input. This signal would be displayed until a new reading was desired.

3.5.3.2 Caution and Warning Capability - The capability for displaying caution and warning signals will be provided in the system design. Four interface pins have been reserved for this function, as noted in paragraph 3.4.7.

3.5.3.3 Up-Data Link Capability - A requirement currently exists to dump recorded data during the astronauts sleep cycle. This capability will be provided over four interface pins. Two circuits will be used to dump T004 data and two circuits will be used to dump data recorded on the remaining recorder. The design will include the capability to inhibit these signals, if required.

3.5.3.4 Status Multiplex Reset - This reset feature will be used to verify the status multiplex system.

3.5.3.5 Capability to Switch between S-017/T004 and the Standard Applications - The capability to time share lines to the S-017 and standard applications will be required in the design. This will be provided by two push button switches on the panel, and the necessary circuits both on the panel and in the carrier.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

1. The lack of a sufficient number of interface pins is the most limiting constraint.

2. In order to accomplish the display and control function for mission 1A, control logic, status multiplex and time sharing capability will be required.

3. A control panel utilizing both individual switches and a logic keyboard was proposed for the 1A design.

4.2 Recommendations - The recommendation of this report is that a system similar to that defined in paragraph 3.4.5 be provided for the 1A mission display and control system.

PR 29-34

TRADE STUDY REPORT

MAINTAINABILITY

AAP/PIP EARLY APPLICATIONS

Contract NAS 8-21004

5 September 1967

Prepared by: K. M. Paser
K. M. Paser

Approved by: J. T. Keeley
J. T. Keeley

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1. INTRODUCTION

The Logistics Study Report (PR 29-18) describes the maintenance philosophy to be applied in support of the 1A mission. The logistics report also contains a general description of the types, levels and locations of the anticipated maintenance operations. With the general system support approach thus defined, the carrier configuration and necessary ground support equipment can be analyzed to determine the ease and economy with which those maintenance operations can be performed. This report provides that analysis and recommends maintainability goals to be considered in the detail design of the mission 1A hardware. Since "no in-flight maintenance" is a specific program ground rule, this report deals primarily with on-pad maintenance operations.

2. SUMMARY

The support approach of sparing "black-boxes" and removing and replacing equipment at that level to perform corrective maintenance causes the placement of these "black-boxes" on the carrier to be especially important as a maintainability feature. This particular aspect of system and subsystem design was analyzed to ensure that the heavier and less reliable modules were the most accessible and could be readily reached with auxiliary handling equipment.

The largest contributor (60%) to the total time required to perform maintenance-malfunction indication and isolation, will be performed in a minimum amount of time and automatically by the "Digital Test Set." This computer controlled system will also provide a high degree of confidence in not launching defective equipment by performing an almost continuous checkout of the more important carrier equipment.

The time-consuming task of realignment after component replacement will also be minimized by careful control of component interchangeability and of truss/alignment plate fabrication to preclude the use of adjustment devices as a part of component installation provisions.

Component and experiment calibration and servicing requirements on the pad will also be minimized by requiring these tasks to be performed primarily at the part level prior to installation on the carrier. On-pad operations then would be limited to a check of alignment and servicing at the subsystem or system level.

Individual component access will be enhanced by truss compartmentization technique with a minimum truss depth. The paneling covering the outer truss areas will be constructed in small, individually removable sections and attached with quick-release fasteners.

3. DISCUSSION

The maintenance philosophy of removal and replacement of carrier/experiments/subsystems components and modules to effect repair of equipment malfunctions will minimize system downtime on the pad. This philosophy causes the placement of replaceable components to be of paramount interest to make the task of component replacement as fast, safe and foolproof as possible. Locating the heavier and/or less reliable system elements in the most accessible locations is one of the most important principles to be observed, especially for this mission 1A carrier configuration. Designing the replaceable components to require a minimum amount of mounting hardware and fluid/electrical connections is another important feature. There are many others that are applicable, and will be determined for incorporation during Phase D.

The sub-tasks of malfunction indication and isolation, equipment alignment, calibration, servicing and checkout for replaceable equipment items must also be treated as important individual considerations in minimizing the complexity and number of maintenance activities to be performed.

3.1 Malfunction Indication/Isolation - Malfunction indication and isolation capability for the mission 1A carrier will be supplied by the Digital Test Set. This system shall be used to checkout and obtain initial system operational status and will monitor system status for the remainder of ground operations. It will be a design goal to automatically indicate and isolate system malfunctions to the replaceable component (black box) level. Historical maintenance data show that on the average, 60% of the total time-to-repair for the typical maintenance task is the time to indicate and isolate the malfunction. Use of the Digital Test Set will reduce this major time-to-repair factor to require seconds instead of hours to accomplish. This fact has been proven by quantitative maintainability analyses on similar automatic/computer checkout and monitoring systems utilized on previous programs.

3.2 Black Box Access - The On-Pad Accessibility Study Report (PR 29-4) provides the analysis of external SLA access and the capability of general carrier area access inside the SLA. Based on that report, visual and physical access to the general areas of all "black box" installations will be available.

The arrangement of support system "black boxes" on truss shelves on either side of the pressure cone is one of the better methods of providing consistently good access to complex "black box" installations. Primary access to the truss mounted support subsystem modules will be from the front face of each truss and the module installations will be designed to provide removal and installation from the front of the truss. Secondary component access (mounting hardware, connectors, etc) will be from either side of the trusses. Small areas on either side of both trusses are used for installation of the four thermal control radiators. These radiators are not considered an access problem, since components which do not require side-truss access can be mounted in those particular truss bays. The trusses will be covered with stressed panels, but the time required for removal of the panels will be minimized by using "quick release" stressed panel fasteners.

Access to the individual components mounted on the truss within the pressure cone is also very good. The concept of a bolted joint between the cone walls and the aft dome permits removal of the entire dome assembly, thus exposing all truss installations from the aft side. The section of the truss which is left open for personnel access also provides individual component access from the top of the truss. Ground support equipment enabling removal/handling of the aft dome will be provided.

Access to experiments/equipment mounted external to the pressure cone in the two aft bays of the external trusses will be gained through removable paneling on either side of the bays. Several experiments in this area are mounted on a common plate for ease of alignment. It will be a design goal to be able to remove and replace these experiment modules either individually or as an assembly with the alignment plate. Access to this alignment plate assembly will be from the aft end of the carrier. This area will not be covered with stressed paneling.

3.3 Alignment - The requirement to realign experiment modules relative to each other or to the carrier centerline after component replacement can be observed with a minimum amount of system downtime. Experiments mounted in the same area which must be aligned to each other and to the carrier centerline will be mounted on a common plate. Dimensional tolerances on the plate mounting pads for mounting the plate itself to the carrier structure and for mounting modules on the plate will be closely controlled. Individual experiments on the plate can be aligned to each other and then the entire plate assembly aligned to the carrier centerline. It will be a design goal to be able to remove and replace modules on the alignment plate without having to perform realignment operations.

Individual experiment modules which are truss mounted and which must be aligned to the carrier centerline can be handled similarly. The dimensional tolerances of the truss structure and mounting pads will be closely controlled, allowing alignment of the truss to the carrier centerline and then alignment of the experiment modules to the truss. Again, it will be a design goal to be able to remove and replace modules on the truss without having to perform realignment operations.

The specific amount of misalignment, however, will have to be measured for several of the experiments. This data will not be used to perform an adjustment to the experiment installation on the carrier, but will be used as a correction factor to be applied to the actual data collected from experiment operations.

3.4 Calibration - The 1A experiments and carrier subsystems require a minimum of calibration for either initial installation or for component replacement action. The few experiment modules which do require calibration for proper operation can be calibrated prior to installation on the carrier. This will prevent downtime on the pad for calibration activities. It will be a design goal to be able to remove and replace carrier components without having to calibrate either the components or the subsystem at the pad.

3.5 Servicing - The requirements for equipment servicing are more extensive. Several experiments require vacuum servicing before and/or after installation in the carrier. Other experiment servicing requirements include filling with helium, leak checking with helium, charging with carbon dioxide, and purging with dry nitrogen. The Thermal Control System will also require considerable servicing in the event of component replacement. The maintainability criteria to be applied in this case is to minimize the amount of and time required to perform servicing operations on the pad, and for that on-pad servicing which is required to ensure the necessary servicing equipment is available, easy to use and the carrier assembly is designed to facilitate on-pad servicing operations.

3.6 Checkout - Most of the checkout after repair requirements will be handled by the Digital Test Set. Some areas will require separate methods and equipment for checkout operations. In these cases, the design of the checkout gear will be monitored to ensure the incorporation of applicable maintainability criteria.

3.7 Component Handling - Whenever possible, equipment to be installed inside the SLA shall be modularized so that weight of each removable unit does not exceed 45 pounds. These units shall be small enough (by volume) for one man to handle and carry. Units weighing from 45 to 60 pounds shall have provisions for a two man lift. When units must exceed 60 pounds, provisions shall be made for mechanical or power lifting. When units weighing more than 45 pounds require lifting more than 5 feet, mechanical or power lift shall be provided. There are several 1A experiments and subsystem modules which do exceed 45 pounds: S040, S017, T004, E06-1, E06-4, E06-7, E06-9, E06-11, batteries (7), and possibly some major modules in the thermal control system. These are the items which will be positioned on/in the more accessible carrier areas, with the items weighing 60 pounds or more being located where they can be handled with auxiliary equipment.

3.8 Maintenance Safety Measures

a. Loose hardware or objects that could fall on the carrier or forward dome of the S-IVB fuel tank will be tethered, or suitably restrained, to prevent carrier or S-IVB tank damage;

b. No articles such as screwdrivers, flashlights, etc., used in the SLA shall be carried in shirt or trousers pockets unless tethered to the individual;

c. All tools used in the SLA shall be securely fastened or tethered to the carrying individual, or carried in a tool box of suitable purpose which is tethered;

d. Sufficient air flow will be introduced into the SLA under normal servicing and checkout conditions to permit ground crews to work for a minimum of two consecutive hours;

e. The scheduling of activities within the SLA shall not expose personnel to toxic or hazardous gases or fluids during loading or venting of those commodities;

f. Operation of all equipment and GSE used inside the SLA shall be verified before such equipment or GSE is brought into the SLA;

g. Normal servicing activities take precedence over contingency tasks except in cases where equipment destruction is imminent or personnel safety is involved;

h. SLA and IU access holes will have suitable protective strips to prevent chafing of fluid and electrical lines passing thru such holes;

i. All batteries shall be activated and load-tested prior to installation on the carrier, within the SLA.

3.9 Lighting Requirements - A general light level of 25 or more foot-candles shall be provided internally within the SLA, between the S-IVB forward bulkhead and level X_a 750.0. The lighting equipment shall be capable of producing localized light levels of 100 foot-candles or more as required for precision work (reference Table VII, MSFC-STD-267) and shall be capable of being relocated to produce higher localized light levels at any point within the service area.

3.10 In-Flight Maintenance - There will be no provisions for repairing in-flight malfunctions of experiments or support subsystems. In the event of simple experiment malfunction, that experiment will be deleted from the operations schedule. In the event of experiment failure that endangers other experiment operation or crew/flight safety, consideration shall be given to jettisoning the failed experiment module or even terminating the flight. Malfunctions in the support subsystems will be handled in a like manner, except that a single failure in a support subsystem could affect several experiments. In that event, a complete review of the experiments operating requirements would have to be made and the experiment operating schedule revised as necessary.

Due to the possibility of experiment/support subsystem module removal and jettison under semi-emergency conditions, it would be desirable to be able to perform package removal operations with the standard command module crew tool kit. This will be given consideration during the detail design phase.

3.11 CONCLUSIONS AND RECOMMENDATIONS

On-the-pad experiment and carrier maintainability was a consideration during the carrier configuration determination and the initial placement of components on and in the carrier. To continue the development of the Mission 1A hardware with potentially good maintainability characteristics, the application of maintainability design criteria as design goals and/or requirements must be accomplished during the hardware detail design. The task of determining this criteria should be accomplished prior to or in the very early part of Phase D so that specific, directly applicable design criteria is available when it will be the most effective.

PR 29-35

TRADE STUDY REPORT

PRELIMINARY RELIABILITY PREDICTION

AAP/PIP MISSION 1A

CONTRACT NAS 8-21004

SEPTEMBER 1967

Prepared By:

Approved By:

Martin Marietta Corporation

Denver Division

1. INTRODUCTION

1.1 Purpose - The purpose of this report is to present the results of the reliability analysis and prediction for the AAP/PIP Mission 1A. To illustrate the predictions comparative to allocated subsystem probability of success.

1.2 Objectives - The analysis was conducted to determine the areas of system complexity that will introduce failure criticality which may violate the constraint of a single failure mode causing mission failure.

The predictions shall be used in Trade Studies to enhance the AAP/PIP Design Concepts. Through redesign or creation of new parts as necessary to achieve mission accomplishment.

2. SUMMARY

The total system predicted reliability is slightly higher than the allocated as noted in Table I. The analysis has been completed, in regards to the data subsystem partial failure or loss of certain data will not degrade the mission.

TABLE I

SUBSYSTEM	RELIABILITY ALLOCATED	RELIABILITY PREDICTED
Structure	0.9999	0.9999
Data	0.9838	0.9776
Display & Control	0.9980	0.9995
Power	0.9940	0.9983
Thermal Control	0.9940	0.9993
Guidance & Navigation	—	0.9975
TOTAL	9700	0.9722

3. DISCUSSION

A configuration baseline has been selected for each subsystem and component. Assumptions and constraints reflecting the most stringent mission profiles and duty cycles include the following:

3.1 Power

a. Seven batteries, each delivering 11.2 KWH, providing a total of 78.4 KWH. With a peak load requirement of 58.7 KW. The excess power capacity of 19.7 KWH represents a unique form of active redundancy. The math model provides for the failure of any one battery-shunt-diode combination. There is 5.7 KWH excess capacity for the EMI bus and 14 KWH excess capacity for the main DC bus "A & B".

b. The rate at which power is consumed is constant over an interval of 336 hours.

c. Switches and controls operate on a cyclic basis in accordance with the schedule in Appendix I.

d. The analysis considers twelve experiments actuated by magnetic latching relays.

e. The first eleven experiments occurring in time are provided power via circuit breaker protected circuits. No protection of the power supply is required for experiment No. 12.

f. An experiment selector matrix, consisting primarily of diodes, switches and relays, is included in the power subsystem.

g. A circuit breaker and a magnetic latching relay for each motor pump are included in the analysis of the thermal control subsystem.

h. The encoder (data subsystem) will function intermittently with 28 on-off cycles.

i. The pallet tape recorder (data subsystem) will function intermittently with 128 on-off cycles.

j. The average operating time for each experiment resetable circuit breaker is 80 hours.

3.2 Thermal Control Subsystem

a. The thermal control system flight operating time used in the reliability math model is 312 hours.

A non-operate failure rate modifier was not used on equipment in the standby mode. This results in an optimistic estimate for equipment in the standby mode.

b. KOP = 1 value (environmental stress factor) was used.

c. Generally the failure rates were not divided into the various failure modes. Therefore the failure estimates include same no effect system failures.

3.2.1 Redundancy Areas

a. Thermal control can be accomplished by either a primary subsystem or a secondary subsystem. Each of these subsystems has its own fluid containers and lines, that is, a leak in one subsystem will not result in loss of fluid in the other subsystem. The primary subsystem includes two pump packages, one of which is in standby. The secondary subsystem with 1 pump package is in standby to the primary subsystem. Switching from the 1st pump to the 2nd in the primary subsystem and from the primary to the secondary subsystem is manual based upon a warning system which utilizes several temperature transducers, a level switch on the accumulators and a differential pressure switch in each subsystem.

3.3 Display and Control Subsystem

The subsystem and experiment controls have been grouped together for ease of operation. Control signals may be issued via the keyboard. The dual scale meter may be used, in conjunction with the keyboard to monitor various subsystem/experiment signals.

3.4 Data Management Subsystem

The experiment and subsystem data are integrated to provide an optimum approach for minimum carrier equipment and maximum possible utilization of experimental data handling system. Real time and delayed transmission of data is possible through the DMS.

a. The signal conditioner contains 25 modules and operates on a continuous basis for 312 hours. For purposes of analysis, the signal conditioner is considered to consist of a 10 volt power supply and 49 discrete data-handling channels. Failure in the power supply would disable all transducers dependent on the power supply while failure in a data-handling channel will result in approximately 2% loss of data.

b. For purposes of analysis, 23% of the encoder failure rate is attributed to failures which would completely disable the encoder. 77% of the failure rate is attributed to failures which would limit the loss of data to a single channel. In an earlier analysis the encoder failure rate was based upon a configuration employing 196 data channels. An AEP encoder with 142 channels would exhibit a mean time between failure of 1945 hours.

c. The PCM encoder and the voltage controlled oscillator operate intermittently for a total of 30 hours.

d. The pallet tape recorder operates intermittently for a total of 90 hours.

e. The CM tape recorder operates intermittently for a total of 13 hours.

3.5 Guidance & Navigation (Pointing & Sensing)

The local vertical manual control is a back-up reference system for guidance & navigation subsystem. The system permits greater flexibility and more extensive use of the AAP/PIP Carrier.

APPENDIX I

POWER SUBSYSTEM PREDICTION

A. Batteries

Let:

E_o = ampere-hours required by the load

E_b = ampere-hours available from each battery

n = number of batteries required to provide a minimum of E_o

E_o - nEb = excess capacity of power supply in ampere-hours

G_{FR} = Generic failure rate in failures/10^6 hours

K_{op} = Operational factor relating severity of environments and failure rate ($\lambda = G_{FR}\ K_{op}$)

I_b = Amperes delivered by each battery.

The mission can be accomplished when:

(1) $$E_o \leqq n \int_o^{t_1} I_b dt + (n-1) \int_{t_1}^{t_o} I_b dt$$

Where t_1 = time at failure of one battery

t_o = total mission time

Solving (1):

$$E_o \leqq \Big[(n\ I_b t\ )\Big]_o^{t_1} + (n-1) \Big[(I_b t)\Big]_{t_1}^{t_o}$$

$$E_o \leqq n\ I_b t_1 + (n-1)\ I_b\ (t_o - t_1)$$

$$E_o \leqq n\ I_b t_1 + n\ I_b t_o - I_b t_o - n\ I_b t_1 + I_b t_1$$

$$E_o \leqq I_b \Big[(n-1)\ t_o + t_1\Big]$$

Appendix I (Continued)

(2) $t_1 = \frac{E_o}{I_b} - t_o (n-1)$

$$t_1 \geq to \left[\frac{E_o}{E_b} - (n-1)\right]$$

$P^n (t_1)$ = Probability of zero failures in interval $(o < t < t_1)$

$P^n (t_o)$ = Probability of zero failures in interval $(t_1 < t < t_o)$

$nP^n Q (t_o)$ = Probability of one failure in interval $(t_1 < t < t_o)$

$$\overset{o}{o}\,{}_o P_o = P^n (t_1) \left[P^n (t_o) + nP^n Q (t_o)\right]$$

OR: $$P_o = e^{\lambda - nt1} \left\{ e^{-n\lambda (t_o - t_1)} + ne^{-\lambda (n-1)(t_o - t_1)} \left[1 - e^{-\lambda (t_o - t_1)}\right]\right\}$$

$$P_o = e^{-\lambda nt_1} \left\{ e^{-n\lambda (t_o - t_1)} + ne^{-\lambda (n-1)(t_o - t_1)} - ne^{-\lambda n(t_o - t_1)}\right\}$$

$$P_o = e^{-\lambda nt_o} + ne^{-\lambda \left[(n-1) t_o + t_1\right]} - ne^{-\lambda nt_o}$$

$$P_o = ne^{-\lambda \left[(n-1) t_o + t_1\right]} - (n-1) e^{-\lambda nt_o}$$

But $t_1 = t_o \left[\frac{E_o}{E_b} - (n-1)\right]$

$$P_o = ne^{-\lambda t_o \frac{E_o}{E_b}} - (n-1) e^{-\lambda nt_o}$$

OR: $$P_o = ne^{-G_{FR} K_{op} to \frac{E_o}{E_b}} - (n-1) e^{-G_{FR} K_{op} nt_o}$$

Appendix I (Continued)

(1) With an excess capacity of 1.0 battery in a 5 battery configuration powering the main DC busses.

P (main DC) = 0.999999

(2) With an excess capacity of 0.75 battery in a 2 battery configuration powering the EMI busses.

P (EMI) = 0.999516

B. Peripheral Equipment =

	ITEM	CYCLES/TIME	GFR/10^{-6}cy-hrs	10^6
1.	Motor Driven Switch (5)	5 cycles	0.564	2.82
2.	Circuit Breakers (14)	336 hours	0.300	100.80
3.	Diodes (38)	336 hours	0.050	16.80
			TOTAL	120.42

P (peripheral equipment) = $e^{-\lambda t} \cong 1 - \lambda t = 1 - 120.42 \times 10^{-6}$

$\cong 0.999880$

C. Static Inverters =

(inverter) = 3.59×10^{-6}
$t = 336$ hours

P (inverter) = $e^{-\lambda t}$ (1-) $\cong 1 - \lambda^2 t^2$

P (inverter) = $1 - (3.59 \times 10^{-6})^2 (336)^2$

$= 1 - 1120 \times 10^{-6}$

$= 0.998880$

Appendix I (Continued)

D. P (power) = [P (main DC)] [P (EMI)] [P (peripheral)] [P (inverter)]

= (0.999999) (0.999516) (0.999880) (0.998880)

= 0.998280

APPENDIX II

Thermal Control Subsystem (Configuration C)

1. Consider one loop of the T-C Subsystem

ITEM	TIME (HRS)	GFR/106	λt
Radiator	312	2.0	0.000624
Freon Boiler	312	2.0	0.000624
Cold Plates	312	2.0	0.000624
Mech. Joints & Fittings	312	0.02	0.000606
Hand Valves (3)	---	Estimate from previous study	0.000003
Orifice (4)	312	0.4	0.000125
Accumulator	312	1.34	0.000418
Thermal Control Valve	312	1.2	0.000374
		TOTAL	0.002798

$R = e^{-\lambda t} \cong 1 - \lambda t = 0.997202$

2. Consider primary mode of operation - pump pkg.

$\lambda t = 5956 \times 10^{-6}$

$R = e^{-\lambda t} (1 + \quad t) \cong (1-\lambda t)(1+\lambda t) = 1 - \lambda^2 t^2 = 1 - (5956 \times 10^{-6})^2$

$R = 1 - 35.5 \times 10^{-6} = 0.9999645$

Appendix II (Continued)

3. In redundant loop omit Freon Boiler

   Then total $\lambda t = 0.002174$

   or $P = 0.997826$

4. Secondary mode of pump pkg. operation involves but one pump.

   Therefore, $\lambda t = 5956 \times 10^{-6}$

   $R = e^{-\lambda t} \cong 1 - \lambda t = 1-0.005956 = 0.994044$

5. Prob. of no failure for Pump (primary mode) and non redundant elements

   $P_1 = (0.997202)(0.9999645) = 0.997167$

6. Prob of no failure for Pump (secondary mode) and associated non redundant elements.

   $P_2 = (0.997826)(0.994044) = 0.991870$

7. Prob. of success for non redundant elements in pump pkg.

   $\lambda t = 636.48 \times 10^{-6}$

   $P_3 = e^{-\lambda t} \cong 1 - \lambda t = 1-636.48 \times 10^{-6} = 0.9993635$

8. $P_o = P_3 \left[1 - Q_2Q_1\right] = 0.9993635 \left[1 - (0.002833)(0.008130)\right]$

   $P_o = (0.9993635)(1 - 0.0000230)$

   $P_o = 0.999340$

APPENDIX III

Data Subsystem

The data subsystem reliability is highly sensitive to the complement of experiments selected for the mission and the quantity of measurements to be made. Assuming experiment descriptions in which 134 digital channels and 37 analog channels are required.

Appendix III (Continued)
Data Subsystem (Continued)

Signal Conditioner - The complement of components for the signal conditioners yields a λ = 60.610 PPM

$\therefore$ P (Sig Cond - Zero Fail) = $e^{-\lambda t}$ $1 - \lambda t = 1 - (60.610 \times 312 \times 10^{-6})$

$= 1 - .018910 = .981080$

P (Sig Cond - One Fail) $= e^{-\lambda t} \cong 1 - \lambda t = 1 - (60.610^2 \times 10^{-12} \times 312^2)$

$\cong 1 - 000350 \cong .999650$

$\therefore$ The 10 volt power supply failure rate is determined to be as noted λ = 5 (B)

P = .998440

P (Sig Cond - one fail) P_{10v} = .998080

(A) Signal Conditioner (Les 10 Volt Power Supply)

The analysis is based upon the following complement of assemblies.

ASSEMBLY	QTY.	CHANNELS/ASSEMBLY
Frequency Demodulator	11	1
DC Differential Amplifier	4	2
Active Attenuator	7	4
Converter, AC to DC	2	1

The total part count is as follows:

Appendix III (Continued)
Data Subsystem Prediction (Continued)

PART	FREQ.DEMOD.	D.C. AMP.	ATTEN.	CONV.	TOTAL
Transistor	165	70	48	18	291
Diode	115	12	24	6	157
Resistor	483	150	120	70	823
Capacitor	125	10	24	20	179
Potentiometer	10	8	0	4	18
Zener Diode	20	10	24	2	56
Inductor	0	8	0	0	8

Failure rates for this complement of parts:

PART	n	$G_{FR}/10^6$ Hrs	(n) $G_{FR}/10^6$ Hrs
Transistor	291	0.10	29.100
Diode	157	0.05	7.850
Resistor	823	0.01	8.230
Capacitor	179	0.01	1.790
Potentiometer	18	0.50	9.00
Zener Diode	56	0.08	4.480
Inductor	8	0.02	0.160
		TOTAL	60.610

(B) 10 Volt Power Supply

Failure rates for the parts complement in the 10 volt power supply are as follows:

Appendix III (Continued)
10 Volt Power Supply (Continued)

PART	n	$G_{FR}/10^6$ hrs	(n) $(G_{FR}/10^{-6}$ hrs
Transistor	20	0.10	2.000
Diode	10	0.05	0.500
Resistor	50	0.01	0.500
Capacitor	10	0.01	0.100
Potentiometer	3	0.50	1.500
Zener Diode	4	0.08	0.320
Inductor	2	0.02	0.040
Transformer	1	0.04	0.040
		TOTAL	5.000

$$P\ 10V\ PWR = e^{-\lambda t} \cong 1 - \lambda t$$

$$= 1 - (5 \times 10^{-6})(312) = 1 - 0.001560$$

VHF Transmitter - Two transmitters operating for 35 hours

λ(PCM) = 42.2×10^{-6} per NA - SID 65 - 1535 "Rel Summary"

$$P = e^{-\lambda t} \cong 1 - \lambda t = 1 - (42.2 \times 10^{-6})(35)(2) = 1 - 2954 \times 10^{-6}$$

P= .997046

S-Band Transmitter and Power Amp. - Assume Operating Time of 4 Hours

λ(S-Band) = 26.10×10^{-6} extrapalated from NA - SID - 65 - 1535 Reliability Summary

$$P = e^{-\lambda t} \cong 1 - \lambda t = 1 - (26.1 \times 10^{-6})(4) = (1 - 104.4 \times 10^{-6})$$

P = .999896

Appendix III (Continued)

Central Time Equipment (CTE) - Operating Time of 336 hours

$\lambda(\text{CTE}) = .0062 \times 10^{-6}$ (SID 65-1535 Ref)

$P = e^{-\lambda t} \cong 1 - \lambda t = 1 - (.0062 \times 10^{-6} \times 336) = P = .999998$

"VHF" RF Triplexer - Assume operating time of 336 hours

$(\text{VHF}) = .01 \times 10^{-6}$

$P = e^{\lambda t} \cong 1 - (.01 \times 10^{-6})(336) = P = .999997$

Tape Recorder #1 - The recorder considered for the program presently available has a mean-time-to-failure (MTBF) = 13,750 hours operation ($\lambda = 72.7 \times 10^{-6}$). Assume an operation time of 90 hours, the reliability is:

$P = .993457$

PCM Encoder - Based on industrial analysis of encoder failure history 23% of encoder failures rate is attributed to failures which would completely disable the encoder.

Encoder = 514 for 142 channel encoder

0.23 encoder $= .23 (514 \times 10^{-6}) = 118.22 \times 10^{-6}$

Assume encoder operates intermittently for 80 hours

$$\therefore P = e^{-\lambda t} \cong 1 - \lambda t = 1 - (118.22 \times 80 \times 10^{-6}) = 1 - .009457$$

$$= .990543$$

Appendix III (Continued)
PCM Encoder (Continued)

$.77\,\lambda(\text{Encoder}) = 0.77\ (514 \times 10^{-6}) = 395.78 \times 10^{-6}$

Compensating for increased complexity of the mission 1A PCM Encoder Requirement, 171 channels of information:

$$(171) = \frac{171}{142}\ (395.78 \times 10^{-6}) = 475 \times 10^{-6}$$

$$P\ (141\ \text{chan - one fail}) = e^{-\lambda t}(1 + \lambda t) + 1 - \lambda^2 t^2$$

$$P = 1 - (475 \times 10^{-6})^2\ (80)^2 = 1\text{-}1444 \times 10^{-6} = .998556$$

$$P_o\ \text{Encoder} = (0.990543)(0.998556) = 0.989100$$

DATA MANAGEMENT SYSTEM

RELIABILITY SUMMARY

	RELIABILITY	
	PREDICTED	ALLOCATION
Signal Conditioner & Distribution Unit	.998080	———
Central Time Equipment	.999998	———
PCM (5.12 KBPS)	.989100	———
Tape Recorder #1	.993457	———
VHF Transmitter (2)	.997046	———
VHF RF Triplexer	.999997	———
S-Band Transmitter & Power Amp.	.999896	———
TOTAL	.977674	.983800

4. CONCLUSION AND RECOMMENDATIONS

a. The predictions for the signal conditioner and the PCM encoder are based upon the acceptability of no more than one failure in each component; with the additional provision that the failure does not disable the entire component. The precedent for this approach has been established in earlier space programs, particularly with regard to data subsystems.

A recent application of this principle involves the Apollo encoder in which NASA requires a mission success probability of 0.9997 for 200 hours with the loss of no more than 5 analog and 8 digital channels.

It is recommended that the specifications for both the signal conditioner and the PCM encoder be written to reflect this concept. In addition, reliability analyses undertaken by the two component manufacturers must differentiate between failures that completely disable the component and failures which affect single data channels.

b. <u>Apportionment</u> - The apportionment of the configuration has been sized to effectively encourage proper design constraints in all subsystems. It is therefore recommended that the allocations of this report be used to revise and update the "Mission 1A Program Technical Requirements and Criteria" document. (chg 25 August 1967).

The math model and reapportionment are as follows:

$$R_i \text{ (allocated)} \quad \frac{\left[1 - R_i \text{ (predicted)}\right]\left[1 - R \text{ (total pallet requirement)}\right]}{1 - \prod_{i-1}^{6} R_i \text{(predicted)}}$$

with the provision that

$$\prod_{i-1}^{6} R_i \text{ (allocated)} - 9700$$

where R_i - reliability of the i^{th} subsystem.

4. CONCLUSION AND RECOMMENDATIONS (Continued)

SUBSYSTEM	RELIABILITY ALLOCATED
Structure	0.9995
Power	0.9980
Thermal Control	0.9990
Data	0.9765
Display & Control	0.9995
G & N	0.9975

PR 29-36

MASS PROPERTIES REPORT

AAP/PIP EARLY APPLICATIONS

✓
RL

Contract NAS 8-21004

1 September 1967

Prepared by: R. D. Hurley
R. D. Hurley

Approved by: W. S. Paulson
W. S. Paulson

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1. INTRODUCTION

This report presents the mass properties resulting from the trade and evaluation studies performed during the AAP/PIP Early Applications study. The basic carrier subsystems, and experiments are for a 14-day mission to be flown in January 1969 or April 1969. The later flight will carry two more experiments.

The weight summary reflects a functional type breakdown by subsystem for each of the flights.

The detailed weight analysis shows a second generation breakdown for each of the subsystems and describes in as much detail as possible the subsystem as currently defined.

2. SUMMARY

The current predicted weight for the January 1969 mission is 5192 lbs and 5408 lbs for the April 1969 mission. The center of gravity location is 13.2 inches forward of the SLA attach points and 1.33 inches radially from the centerline.

3. DISCUSSION

3.1 Carrier Weight Summary - The weight summary in Table 1 shows a functional breakdown of the subsystems with values for both January 1969 and April 1969 launch dates. The later launch date configuration contains two additional experiments: S039 Day-Night Camera and S040 Dielectric Camera. These two experiments require the addition of a Unified S-Band System in the Data Management area and contamination covers and mechanisms for the camera lenses.

The detail analysis shows the derivation of each of the subsystem weights shown in the summary.

3.2 Detail Weight Analysis

3.2.1 Structure - The structure weight breakdown includes the basic carrier structure as well as equipment racks, camera truss, meteoroid protection and contamination covers, etc.

The basic carrier structure, camera truss, and equipment rack weights are derived from stress analysis based on hand calculations and computer programs and the use of preliminary layout drawings. The meteoroid protection required is the result of a computer analysis. The docking ring and drogue assembly weights are based on existing Apollo hardware. A suitable weight contingency factor based on experience is applied to total structure weight to allow for details not covered in the current data sources but are required for design completeness. A detailed description of the structure configuration is presented in Structural Configuration Description, PR 29-37.

3.2.2 Subsystems - All subsystem weights are based on existing hardware with appropriate allowances for interconnecting

CARRIER WEIGHT SUMMARY

	Launch Date	
	April (lbs)	January (lbs)
Structure	1167	1167
Electrical Power	1484	1484
Attitude Control	46	46
Data Management	333	290
Display and Control	178	178
Thermal Control	357	357
Subsystem Support	240	236
	3805	3758
Experiments	1218	1074
Experiment Support	125	110
	5148	4942
Growth Allowance	260	250
	5408	5192

TABLE I

wire or plumbing. A few items such as the cold plates in the thermal control system are development items.

The experiment weights are based on existing hardware, modifications of existing hardware, or in some cases, redesign of components.

A contingency factor is included in the total weight for each subsystem except experiments. A subsystem support weight for mounting equipment is included as a percentage of overall subsystem weight.

3.3 Center of Gravity - The present ground rule for center of gravity (c.g.) location is that it must be within a 36 inch radius sphere which has its center at the intersection of the SLA attach points and booster axis.

The c.g. analysis indicates the location to be 13.2 inches forward and 1.33 inches radially from the intersection point. The c.g. of the carrier/CSM combination must be within a cone which is within the control cone defined by the engine gimballing capability. Both c.g. locations meet these requirements.

3.4 Breakdown of Detail Weights - The following tables show component detail weights for each subsystem shown in the summary.

Structure

Skin	94
Docking Ring and Fwd Frame	33
Longerons	27
Dome	40
Dome Flanges w/bolts	45
Windows w/frames	55
Airlock w/frames	53
Support Trusses	277
Truss Attach Ftgs.	21
SLA Attach Ftgs.	22
Internal Truss w/ftgs.	23
External Racks	137
Drogue Assembly	30
Contamination Covers & Mechanisms	75
Meteoroid Protection	40
Contingency	195
Total	1167

Attitude Control

Horizon Scanners (2)	9
Electronics	10
Gyro & Electronics	15
Sun Sensors (4)	1
Wire, Connectors, Clamps, etc.	7
Contingency	4
Total	46

Electrical Power

Batteries (7)	980
Inverters (2)	60
Switches (6)	21
Circuit Breakers	6
Diode Pkgs	20
Wire Connectors, Panels, Busses, etc	326
Contingency	71
Total	1484

Thermal Control

Active System	
Radiator	45
Pump Pkg	7
Freon Boiler	1
Cold Plates	79
Valves & Disconnects	2
Orfice	2
Accumulator	9
Lines & Fittings	22
Freon 21	100
Passive System	
Insulation	23
Attachments	25
Contingency	32
Total	357

Display & Control

D&C Panel in CSM	85
CSM Wiring, Clamps, etc.	25
Control Logic	4
Sequencer	5
Display Logic	4
Carrier Wiring, Clamps, Busses, etc.	28
Contingency	27
Total	178

Data Management

Signal Conditioner	30	
PCM	35	
Recorder	15	
S-Band Xmtr	13	Remove for Jan.Flt.
S-Band Pwr. Amp	24	
S-Band Signal Switch	1	
S-Band Antenna	1	
CTE	7	
VHF Xmtrs (3)	15	
VHF Amplifiers	2	
VHF Antenna	5	
S017 Data System	70	
Support Camera	35	
Wire, Connectors, Clamps, etc.	50	
Contingency	30	(26)
Total	333	(290 for Jan.Flt.)

Experiments

S039 Day-Night Camera	61
S040 Dielectric Camera	83
S043 Infrared Temp. Sounder	45
S044A Elec. Scan Micro Radiometer	20
S048 UHF Sferics	31
S017 X-ray Astronomy	222
S019 UV Stellar Astronomy	43
S020 UV X-ray Solar Photo	25
D017 CO_2 Reduction	32
S015 Zero-g Single Human Cell	22
T003 Inflight Nephelometer	5
T004 Frog Otolith	86
E06-1 Metric Camera	200
E06-4 Multispectral w/extra film	55
E06-9 Infrared Radiometer/Spectrometer	80
E06-7 Infrared Imager	120
E06-11 Microwave Radiometer	50
D008 Radiation	5
D009 Simple Navigation	12
S016 Trapped Particle	8
S018 Micrometeorite	6
T002 Manual Navigation	7
Total	1218

PR 29-37

TRADE STUDY REPORT

STRUCTURAL CONFIGURATION DESCRIPTION REPORT

AAP/PIP EARLY APPLICATIONS

Contract NAS 8-21004

September 1, 1967

Prepared by: K. W. Kohlenberg
K. W. Kohlenberg

Approved by: W. Paulson
W. Paulson

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1. INTRODUCTION

1.1 Purpose - The purpose of this report is to describe the structural features of the selected carrier configuration.

1.2 Objective - The objective of the engineering effort which culminated in the design described in this report, was to develop a feasible structural configuration to be used as a baseline for future optimization efforts.

2. SUMMARY

A brief general description of the selected configuration is presented followed by a more detailed description of the major structural features.

3. STRUCTURAL CONFIGURATION DESCRIPTION

3.1 General Description - The selected carrier configuration, shown in Figures 1, 2, and 3, mounts the experiment sensors in an axial viewing attitude. The pressurizeable portion of the carrier called the pressure chamber assembly is in the shape of a truncated circular cone expanding from the docking tunnel diameter to an 84 inch diameter at the spherical segment aft closure. Four truss assemblies support the carrier in the SLA, and provide the necessary SLA support during the boost phase of flight.

The pressure chamber houses only those experiment components which require data retrieval via direct crew access. Adequate volume is provided for crew IVA and for stowage of various items of equipment during launch and subsequent orbital activities. The balance of the experiment components are mounted on earth facing platforms located on opposite sides of the spherical aft closure. In addition, one large lightweight antenna assembly is supported by one of the trusses.

Support subsystem components are mounted on two equipment racks each supported by two longerons and two experiment platforms support members. The thermal control system radiators are attached to the sides of the equipment support racks.

3.2 Structural Description - The pressure chamber is composed of two major sub-assemblies, the sidewall and aft closure structures.

3.2 Structural Description - (Continued)

The conical sidewall sub-assembly is a welded structure made of 2219 aluminum alloy, consisting of four machined longerons welded to four skin quarter panels. This sub-assembly is welded, at its small end, to the docking tunnel-kick-frame assembly and, at its large end, to the aft closure bolting ring - kick frame to create the side-wall assembly. Truss attach fittings are bolted to the assembly at the junctures of the longerons with the kick frames. The bolts used to attach the fittings do not penetrate the pressure shell.

The spherical segment aft closure is a spin-formed 2219 aluminum alloy shell, welded to a rough machined forged bolting flange with final machining of the flange and chemical machining of the shell being accomplished after welding. An "O" ring is used as the pressure seal at the interface of the closure and the sidewall assembly.

The Z axis trusses (oriented fore and aft in orbital attitude) are each composed of four tubes. Adjustable rod ends are provided for attachment to the fittings located on the pressure chamber and fixed lugs are used for attachment of the tubes to the SLA attachment fittings. Secondary truss members are added to the truss located on the +Z axis to provide support for the microwave radiometer experiment antenna array.

In addition to supporting the carrier in the SLA and providing SLA support, the Y axis trusses are designed to support the experiment mounting platforms and the equipment racks. The lower truss members are square tubes which are welded into a frame to provide support for the earth facing platforms. The equipment racks each consist of four shelves supported by triangular side panels which are riveted to the longeron, the experiment platform mounting frame and the truss support member. Shelves are attached to the side panels by means of shelf support members. A removeable load carrying trapezoidal cover completes the rack structure. This cover along with the side panels provides meteoroid protection for components located on the shelves. The side panels provide support for the TCS radiator assemblies. A thin aluminum alloy meteoroid bumper covers the two unshielded quadrants of the pressure chamber.

3.2 Structural Description - (Continued)

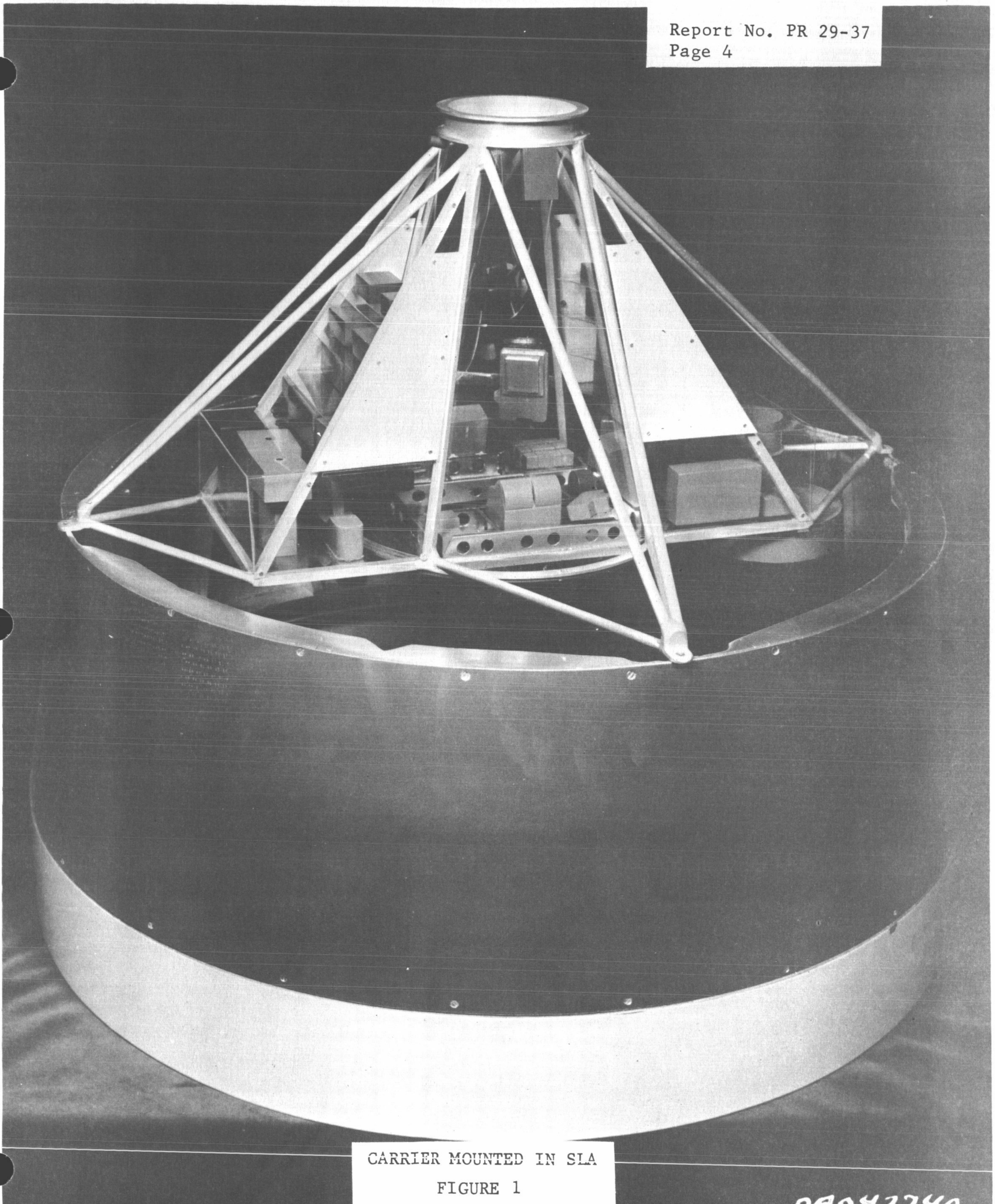
Provisions for pressure chamber wall penetrations such as windows, scientific airlocks, and wire bundle feed throughs are designed to minimize leakage. In general, frames for these penetrations will be machined to the proper configurations as separate parts and then butt welded into cutouts in the skin panels and aft closure.

The experiment support frame, located inside of the pressure chamber, supports several experiments in their operating locations and provides stowage locations for other experiments when they are not operating. This frame also provides direct load paths between the Y and Z axis truss attachments at the large end of the chamber.

IVA handholds and other maneuvering aids will be attached to the longerons which incorporate internal flanges designed for this purpose.

4. CONCLUSIONS AND RECOMMENDATIONS

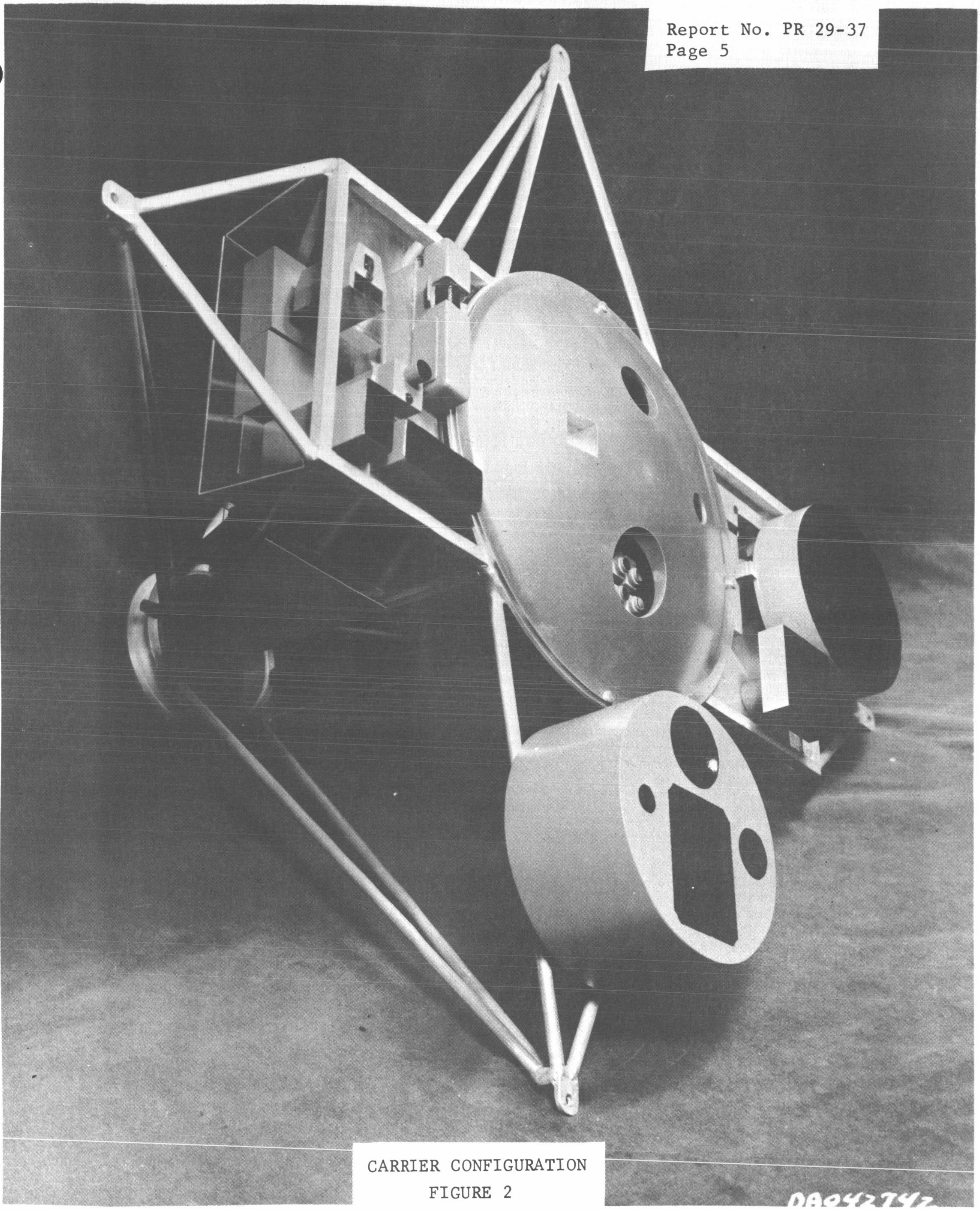
The structure described in this report represents a feasible baseline configuration. As requirements for subsystem and experiment components as well as crew ground viewing and IVA are revised and firmed up, minor changes will need to be studied in order to reach an optimum configuration.



CARRIER MOUNTED IN SLA

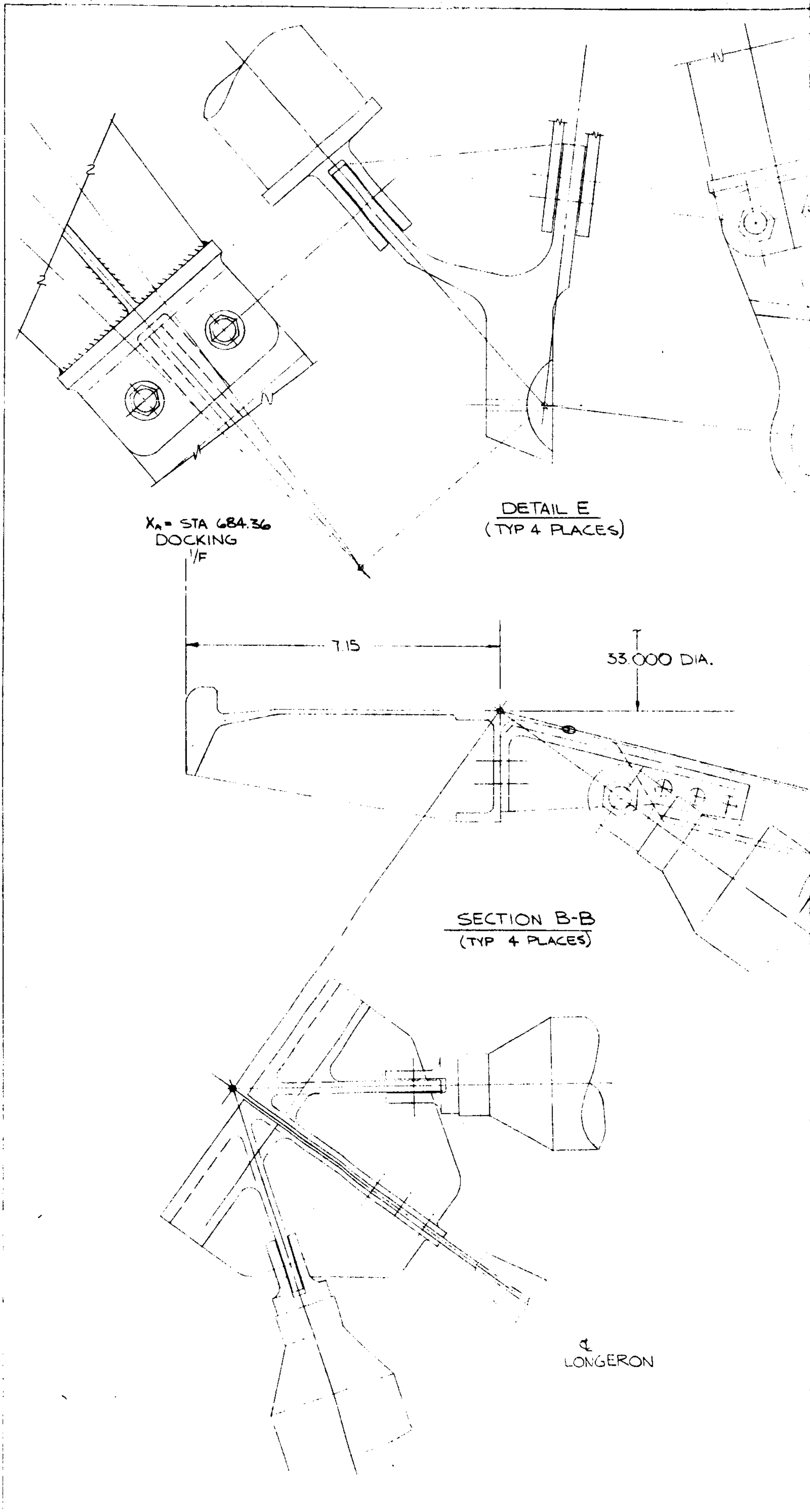
FIGURE 1

DA042740

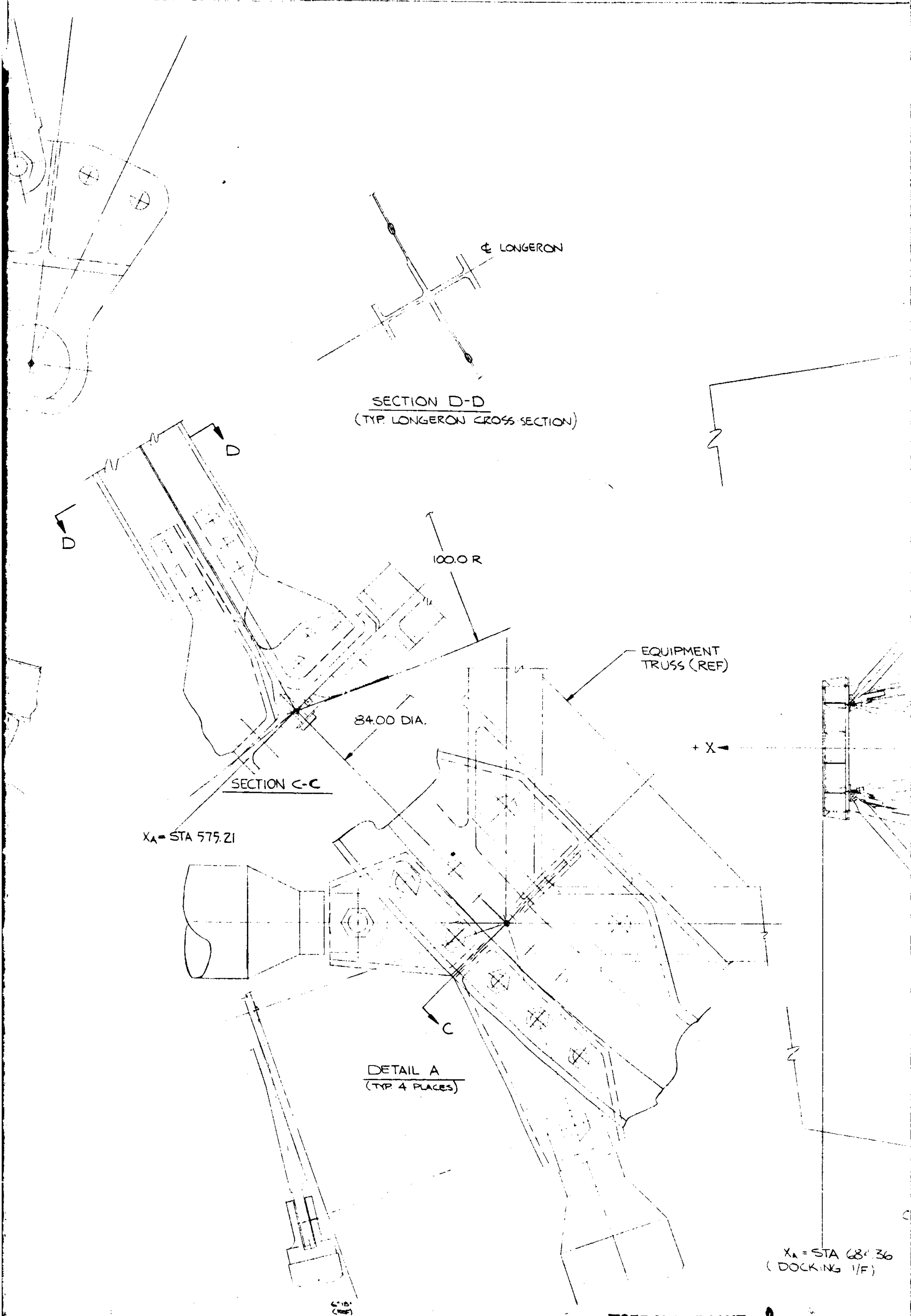


CARRIER CONFIGURATION
FIGURE 2

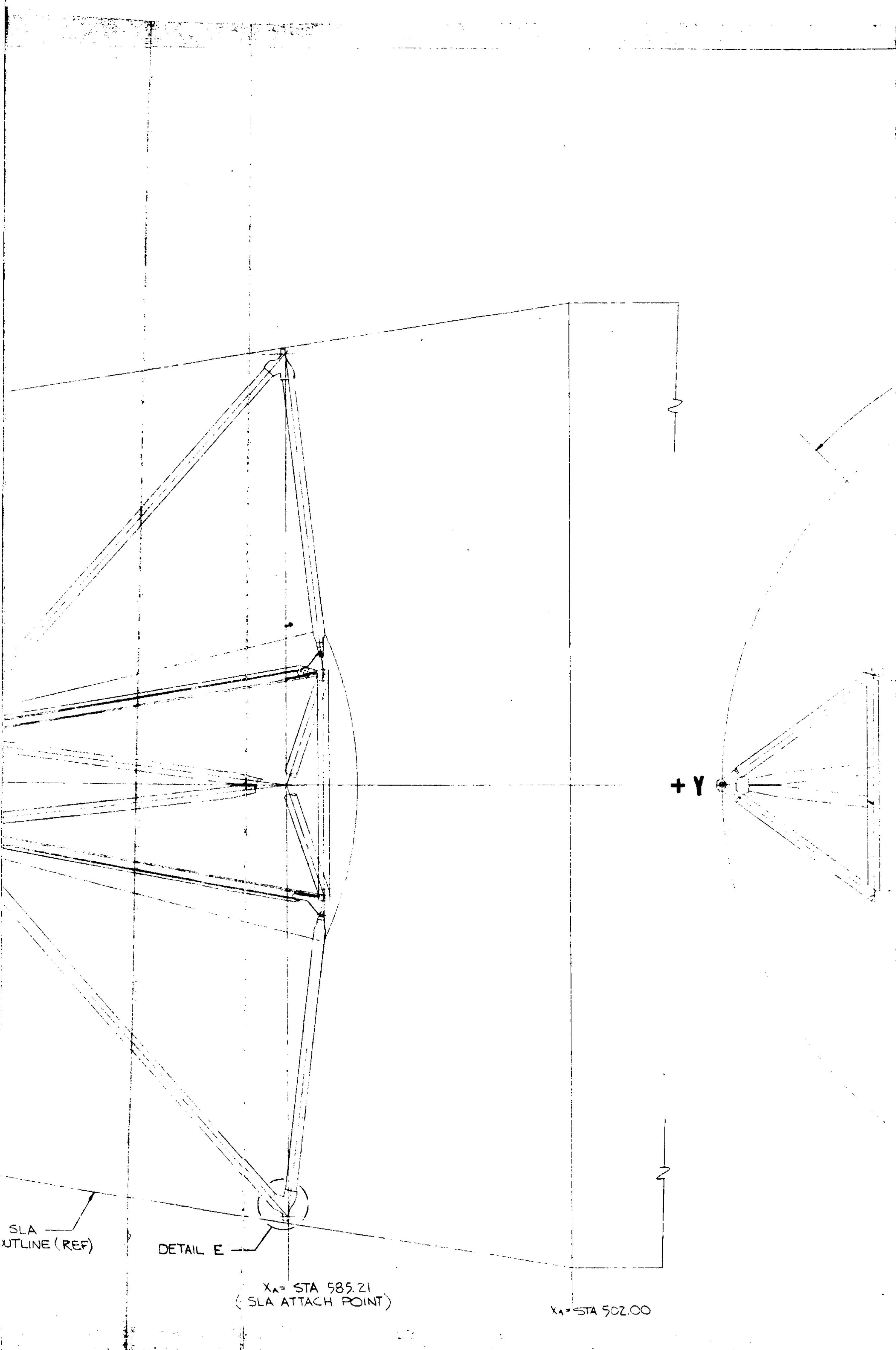
DA042742



FOLDOUT FRAME 1



FOLDOUT FRAME 2



FOLDOUT FRAME

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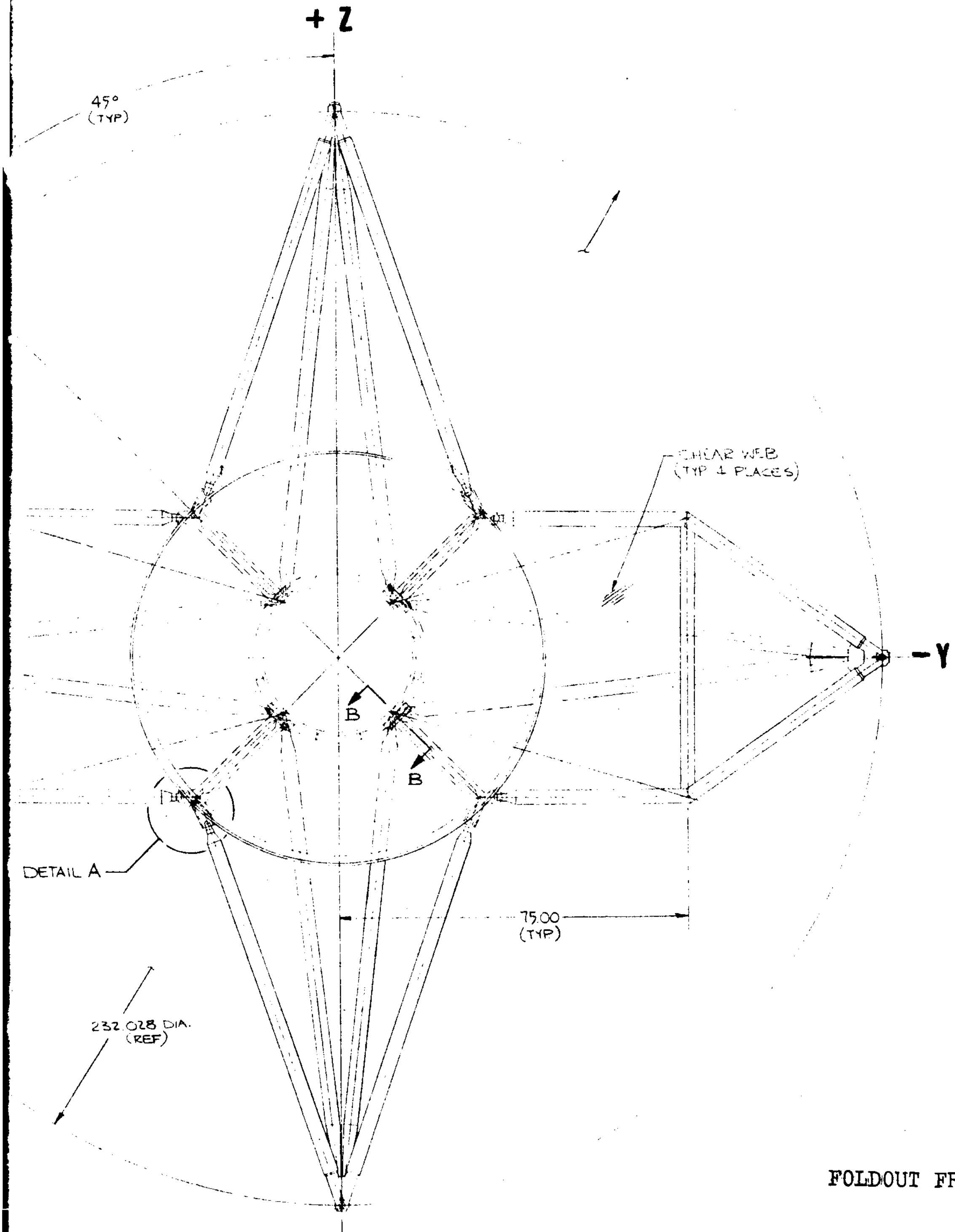
Pg 6

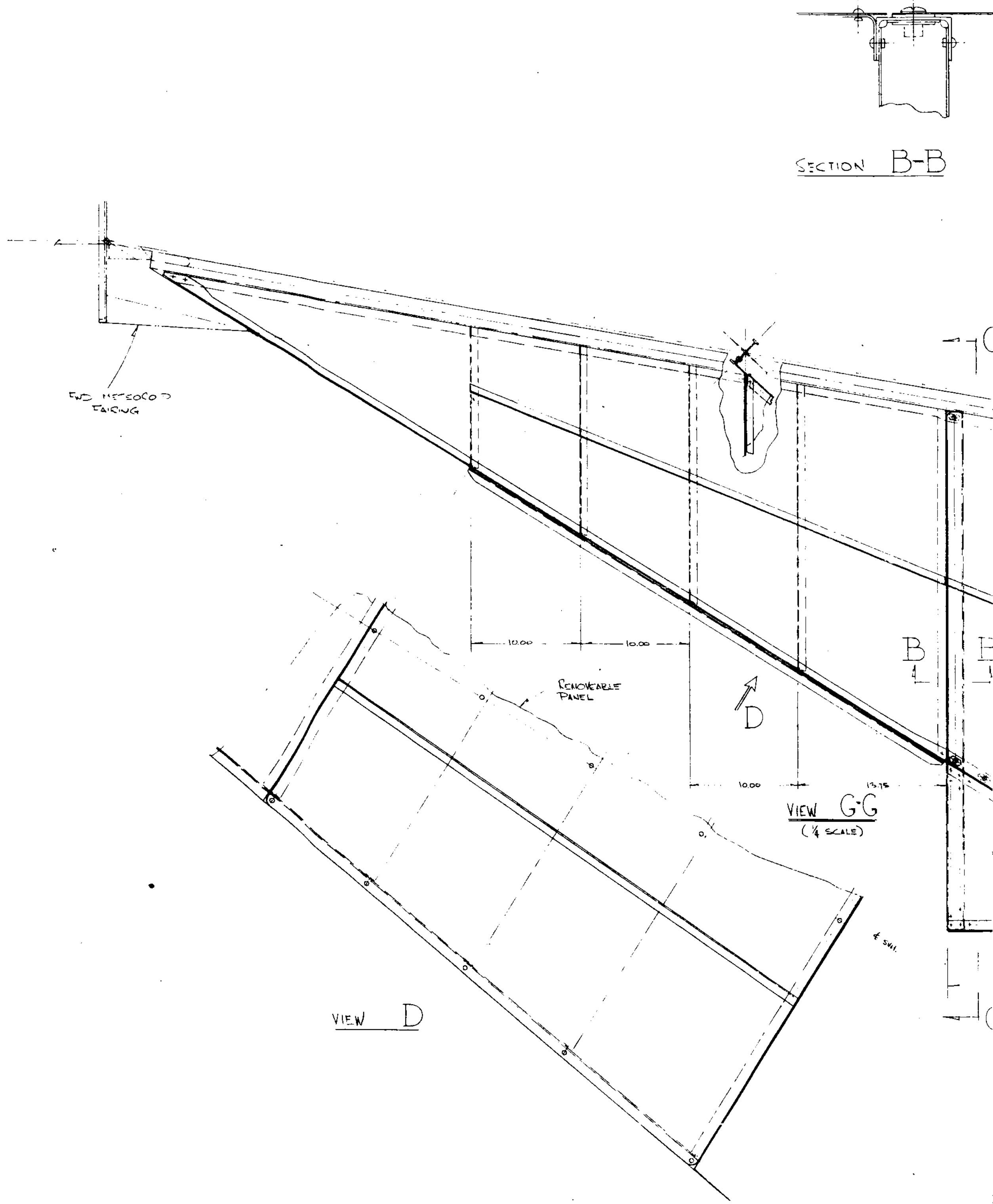


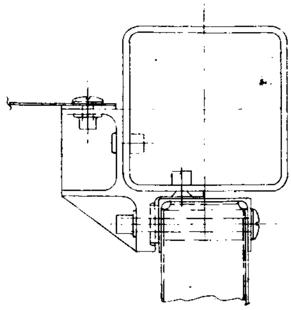
FOLDOUT FRAME 3

MARTIN MARIETTA CORPORATION

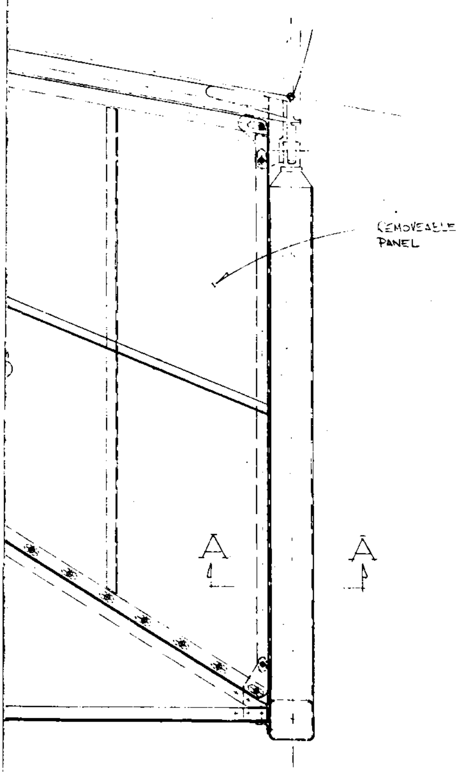
AAP/PIP IA CARRIER
STRUCTURAL CONFIGURATION

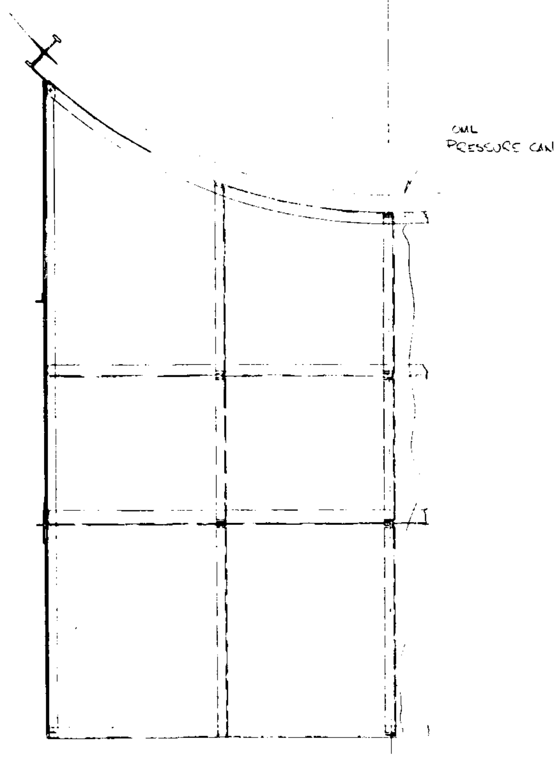
FIGURE 3 SHT 1 9.5.1967


SECTION B-B
REMOVEABLE PANEL
10.00
10.00
10.00
13.75
D
B
VIEW G-G
(1/4 SCALE)
VIEW D

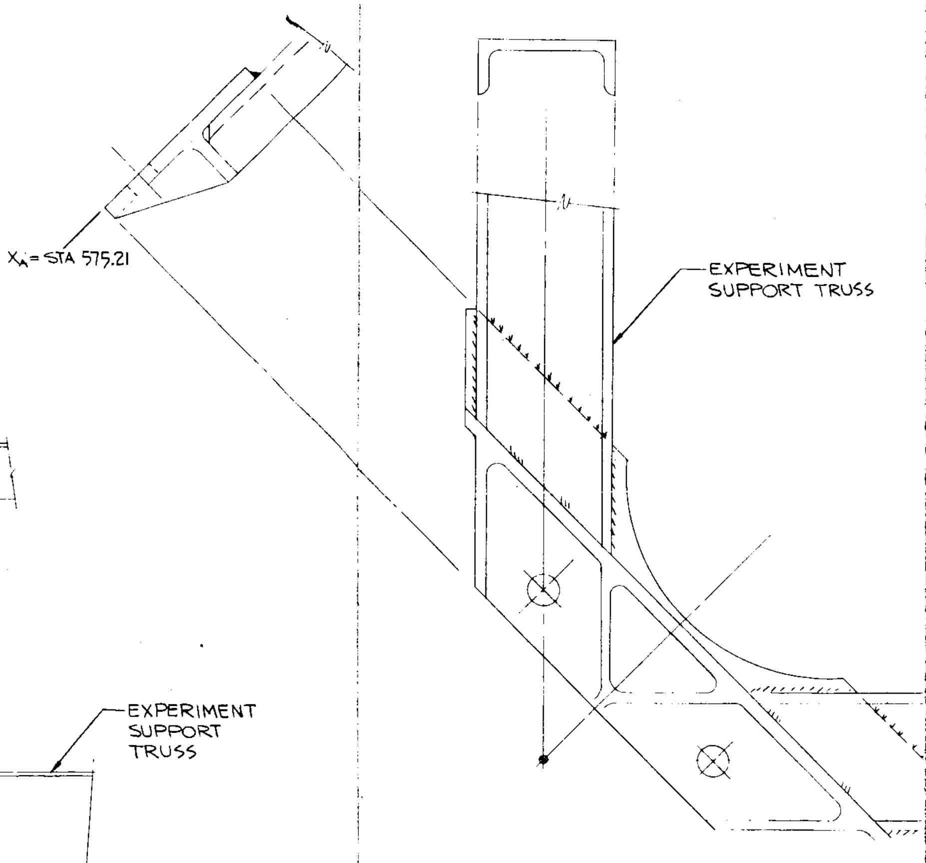


SECTION A-A

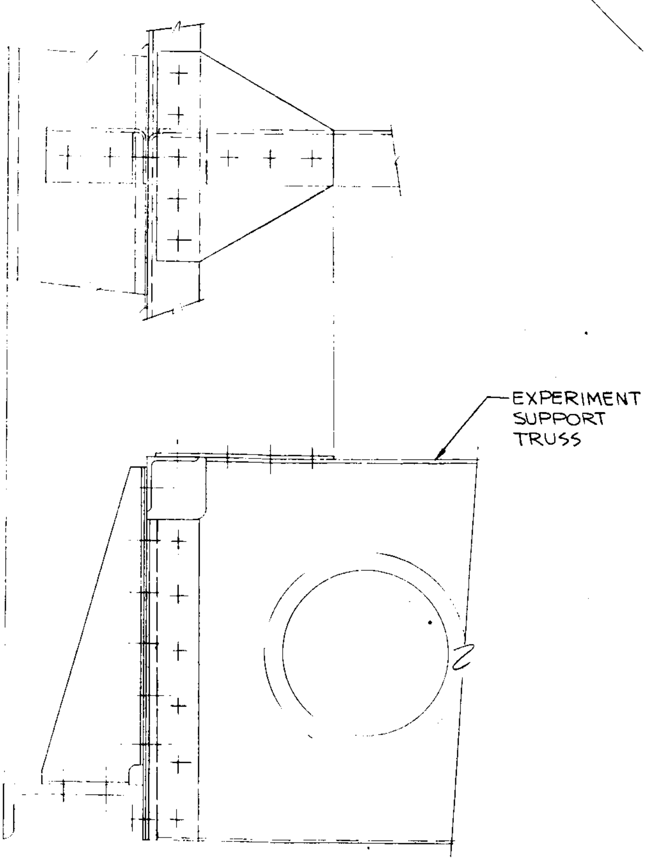




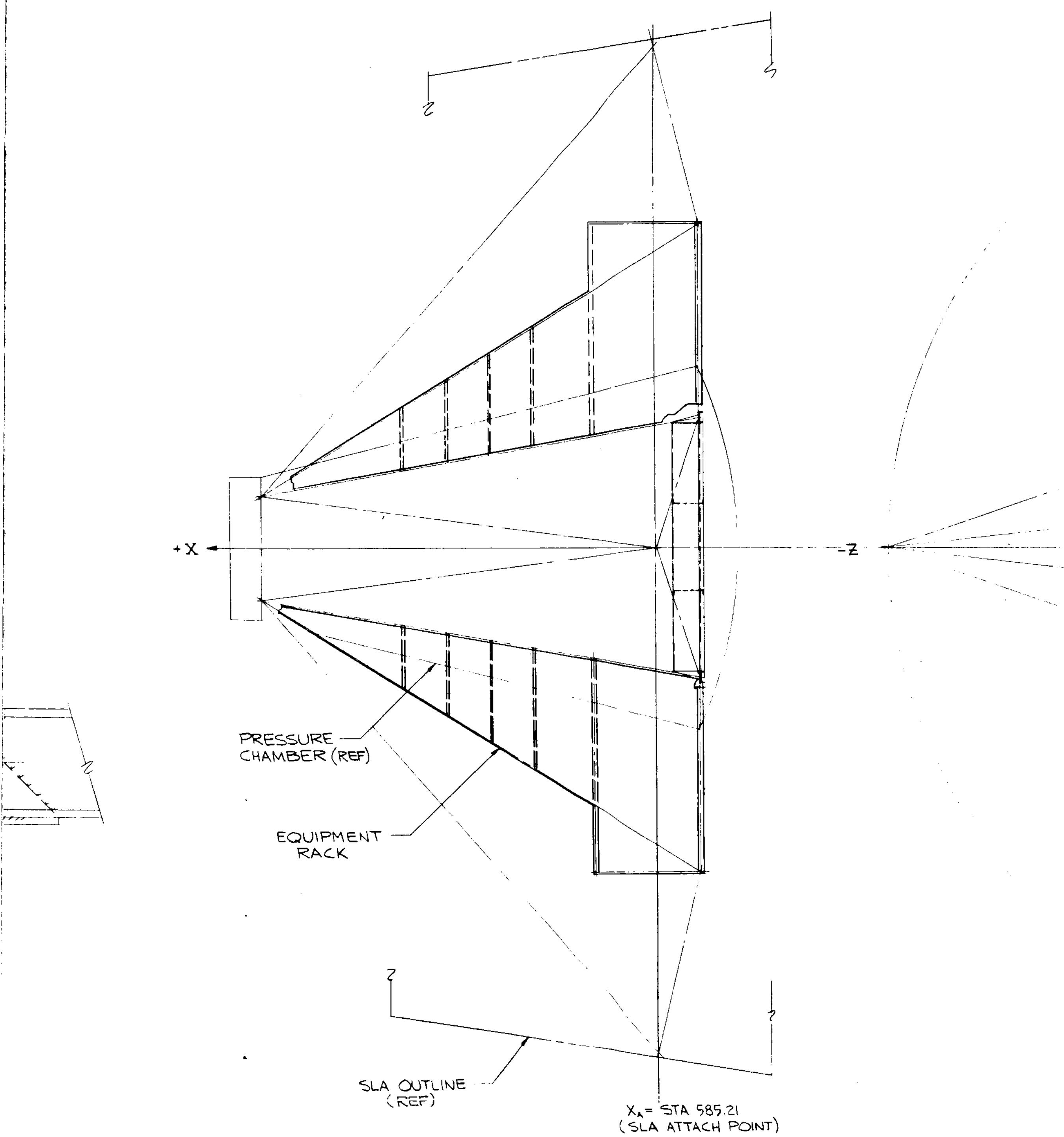
SECTION C-C



DETAIL E
(TYP 4 PLACES)



SECTION F-F



FOLDOUT FRAME 4

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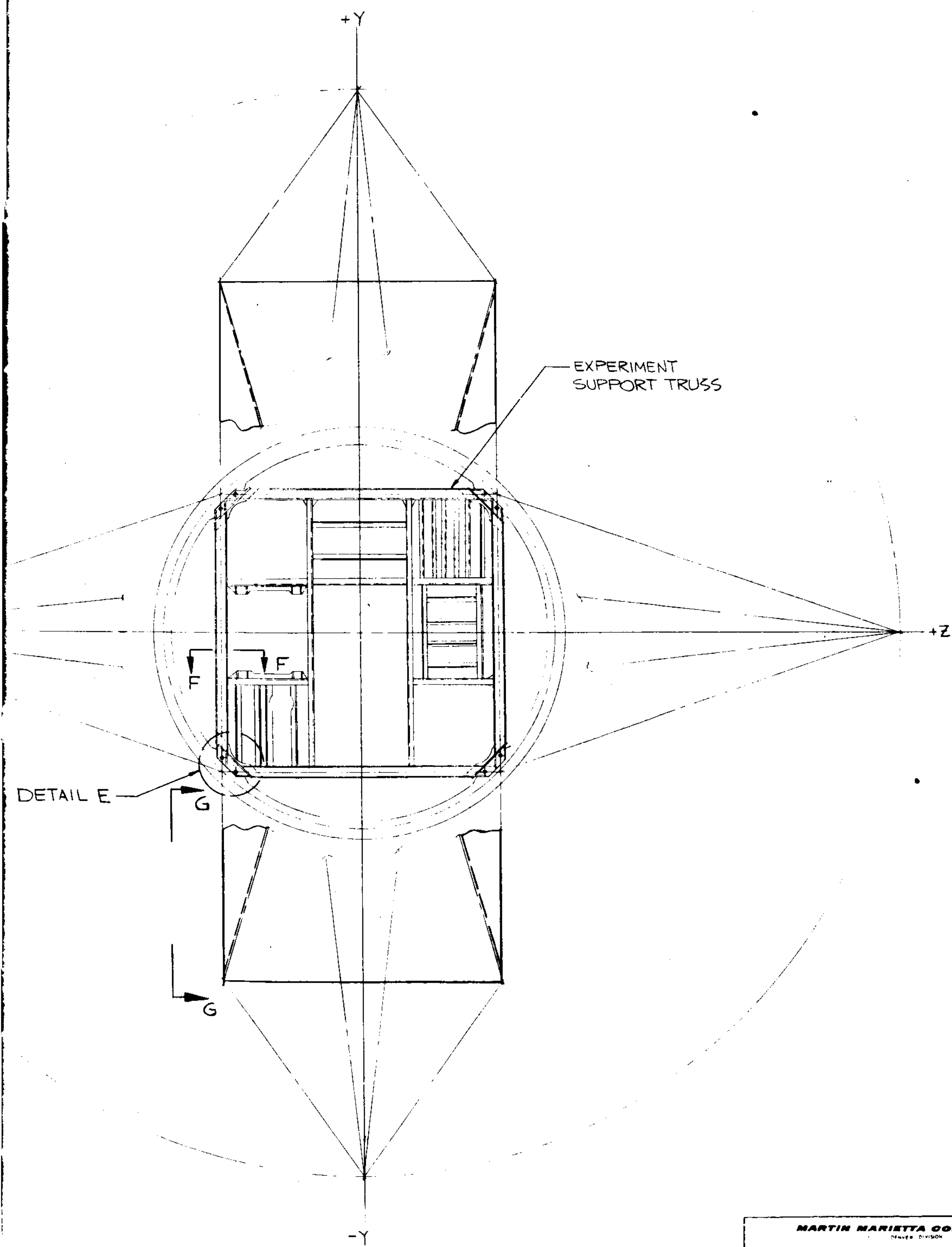
Pg 7



MARTIN MARIETTA CORPORATION
DENVER DIVISION

AAP/PIP IA CARRIER
STRUCTURAL CONFIGURATION

FIGURE 3 SHT 2 9.5.1967

FOLDOUT FRAME 5

PR 29-38

EXPERIMENTS AND SUBSYSTEM INSTALLATION REPORT

AAP/PIP EARLY APPLICATIONS

Contract NAS 8-21004

September 1, 1967

Prepared by: K. W. Kohlenberg
K. W. Kohlenberg

Approved by: W. Paulson
W. Paulson

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1. INTRODUCTION

1.1 Purpose - The purpose of this report is to describe the location and installation of experiments and subsystems in the selected carrier configuration.

1.2 Objectives - The objective of the engineering effort which resulted in the design described in this report, was to develop a feasible arrangement of experiment and subsystem components to be used as a baseline for future efforts.

2. SUMMARY

The locations of the experiment and subsystem components is discussed along with the major reasons for their choice.

3. DISCUSSION

Figures 1, 2 and 3 show the arrangement of experiment and subsystem components in the selected carrier.

The basic ground rule established to guide the study of the location of experiment and subsystem components, was that only those components requiring data retrieval via direct crew access should be located in the carrier's pressure chamber.

This dictated that the Multi-Spectral Camera and Metric Camera experiments and the experiment Support Camera be mounted in the pressure chamber. These cameras view their objectives through windows located in the pressure walls, and are mounted on the experiment support frame. The spare film Cassettes for the Multi-Spectral Cameras are stowed adjacent to the cameras. Experiments which are supported on the frame when they are not operating include D009, T002, S016, S018, S019 and S020.

Another experiment requiring crew access for data retrieval is the IR Imager. However, since the operation of this experiment requires a direct view of its objective without looking through a window, the experiment is mounted on one of the experiment mounting platforms in an unpressurized part of the carrier. A film transport device is used to take exposed film through the pressure chamber wall into a film cassette, which is located in an airlock.

In addition to these components, two N.A.A. designed scientific airlocks are mounted on the pressure chamber. One airlock, to be used for deployment and retrieval of the S016 Nuclear Emulsion experiment, is mounted on the spherical segment closure. This location was chosen to permit the desired deployed orientation of the experiment. The other airlock is attached to the conical portion of the pressure chamber. The S018 Micrometeorite Collection, the S019 UV Stellar Astronomy and the S020 UV X-Ray Solar Astronomy experiments share time on this airlock. Location of the unit was chosen to satisfy viewing and orientation requirements of the experiments, and to facilitate crewman ability to sight through viewers in two of the experiments.

The remainder of the experiments with the exception of the Microwave Radiometer, which is supported by the +Z axis truss, are located on the two experiment support platforms which are attached to the +Y and -Y axes trusses. The locations of these experiments were chosen after considering preliminary sensor viewing requirements, the carrier c.g. location, and access for pre-launch installation, removal, adjustments, and checkout. One component requiring special consideration is the Day-Night Camera. Since the image orthicon tube's major axis must not be colinear with the booster thrust vector, the camera must be mounted on a mechanism capable of supporting the camera during launch and then moving it to the operating attitude. Since little is known about the mounting requirements of many of the experiment components, detailed installation designs have not yet been developed. It is quite possible that some of these components will need to be relocated and reoriented as viewing and mounting requirements are coordinated with the experiment contractors.

Subsystem components are located on the eight shelves which are provided on the two equipment racks. Factors influencing the locations of components on the shelves include sizes and required orientations of components, space available on shelves, carrier c.g. location, minimization of wire runs and fluid lines, and access for pre-launch installation, removal, adjustment and checkout of units. Again, since only preliminary definitions of individual subsystem major components are available at this time, their sizes, locations and orientations shown may change.

The need for contamination control devices to prevent unacceptable degradation of sensor operation has been established for several of the experiments. Although the orientation of the carrier with nearly all experiment sensors looking away from the CSM minimizes the CSM emitted contaminant problem, contamination control is still considered necessary. However, it is assumed that the covers need not be gas tight, but must be capable of excluding relatively small particles. Thermal and meteoroid protection is provided integral with the covers.

Since the pressure chamber mounted experiments look through windows, covers are provided to protect the windows during extended non-operating periods. These covers are positioned by electro-mechanical actuators located outside of the chamber. Since the possibility of actuator malfunction exists, a manual override is provided for actuating the covers. Pressure wall penetrations, as well as cost and weight may be minimized by using one actuator to position several covers where this proves feasible.

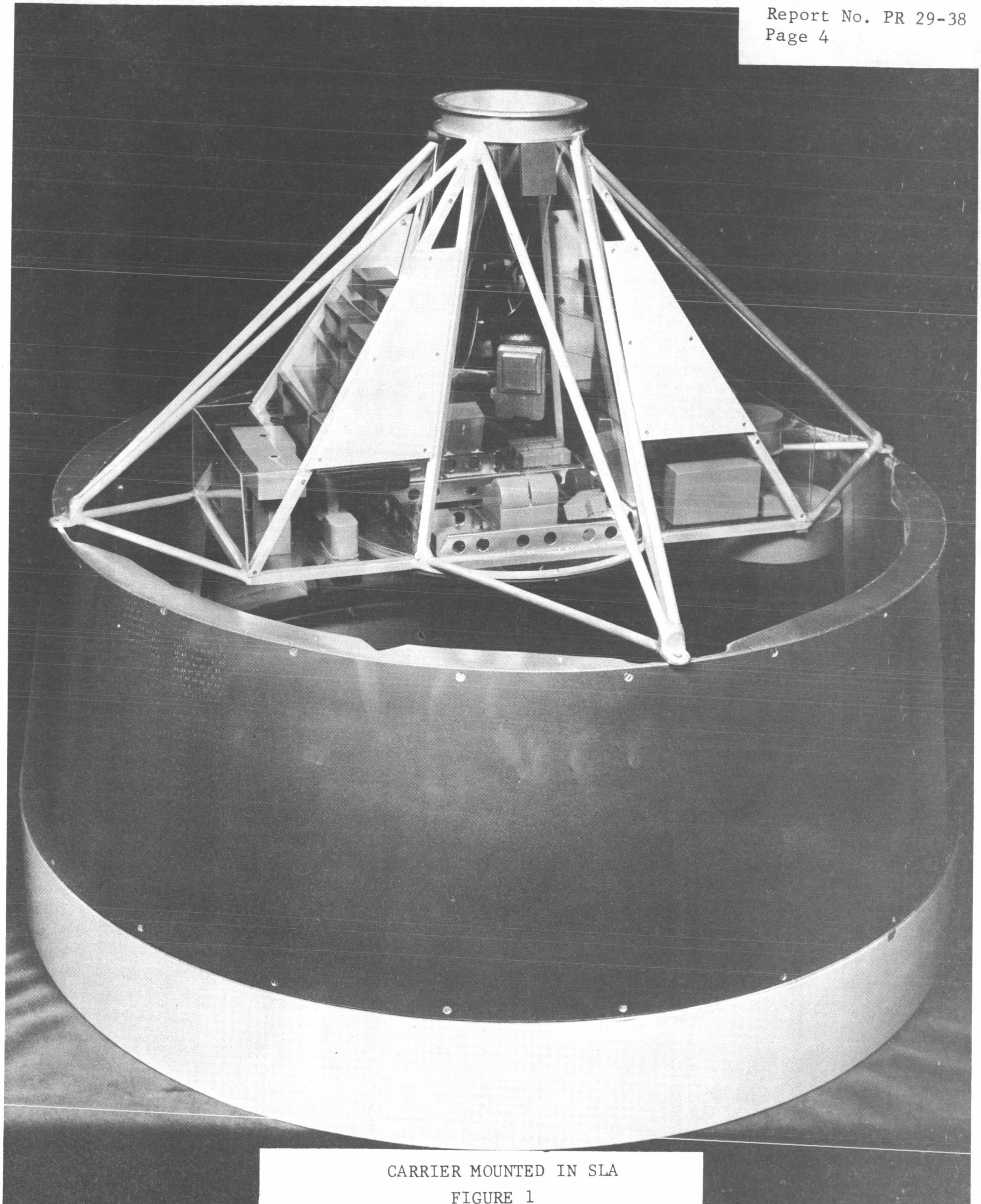
Experiments located on the platform will be protected with covers in a similar manner. However, since sensor aperture sizes and shapes vary greatly, interfaces for the covers will be mounted on the platforms to facilitate cover sealing to exclude contaminants.

Passive thermal control for the entire carrier is provided by multi-layer insulation blankets attached to the exterior surfaces of the equipment racks and experiment mounting platforms, and to the aft closure and the two unshielded quadrants of the pressure chamber. Cutouts in the blankets are provided for sensor viewing where the insulated contamination control covers provide protection.

A thin aluminum alloy meteoroid bumper covers the two unshielded quadrants of the pressure chamber. The contamination control covers provide protection for the sensor aperture and the sensor viewing windows.

4. CONCLUSIONS AND RECOMMENDATIONS

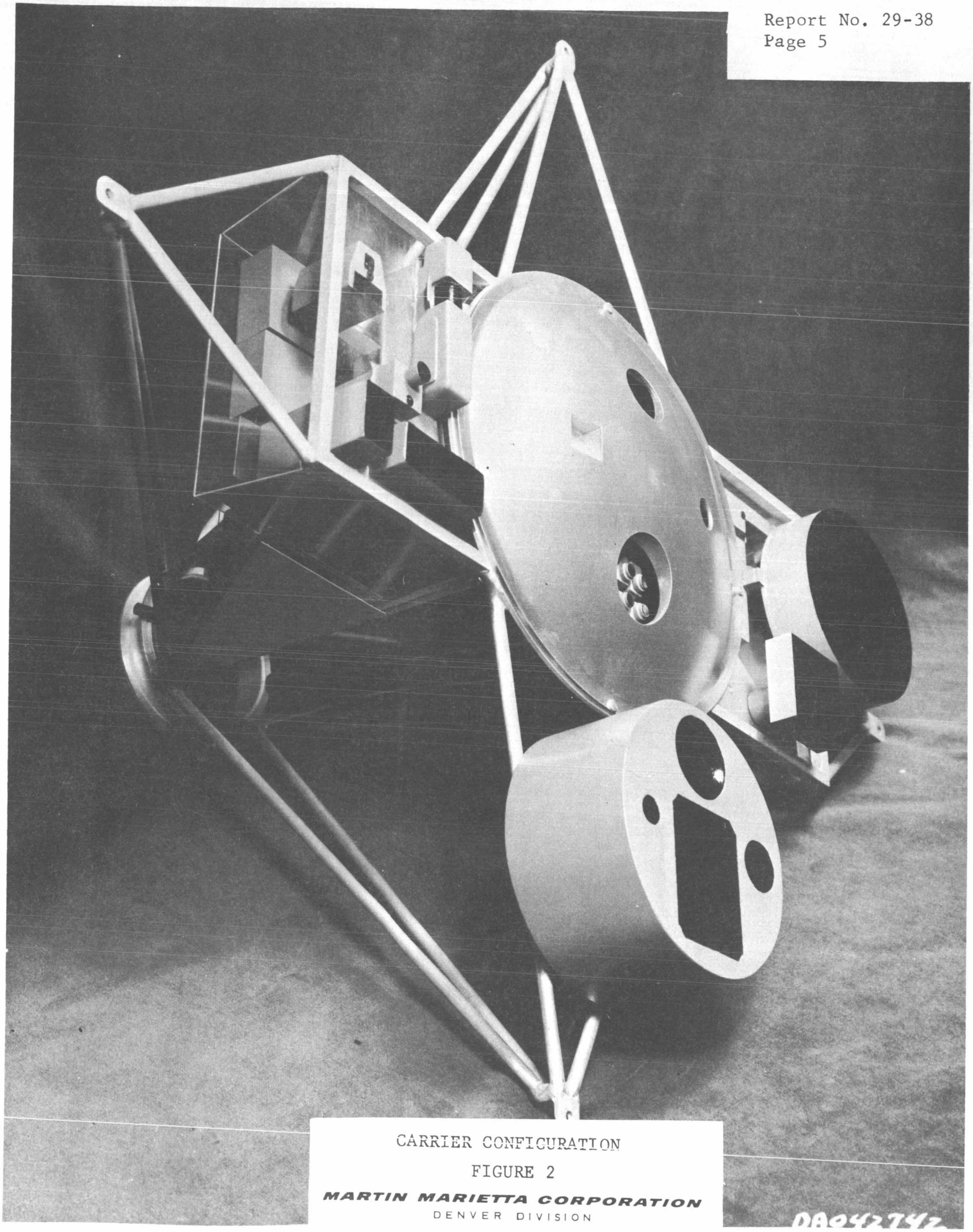
The experiment and subsystem installation arrangement presented in this report represents a feasible baseline configuration. Additional and modified requirements for subsystem and experiment components and for crew ground viewing and IVA will influence the development of the final configuration.



CARRIER MOUNTED IN SLA

FIGURE 1

DA042740

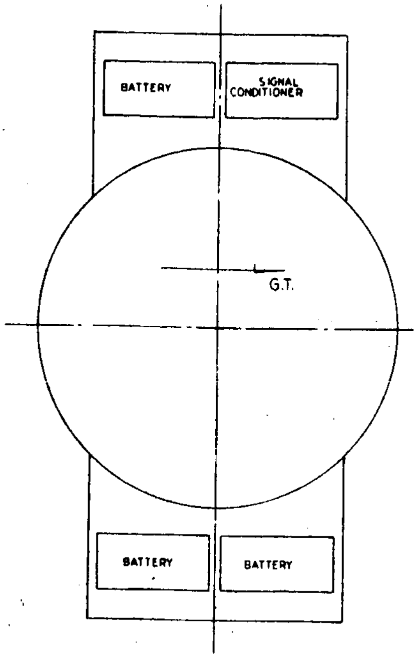


CARRIER CONFIGURATION

FIGURE 2

MARTIN MARIETTA CORPORATION
DENVER DIVISION

DA042742



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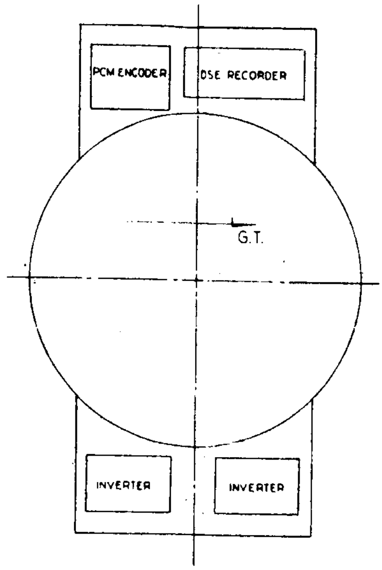

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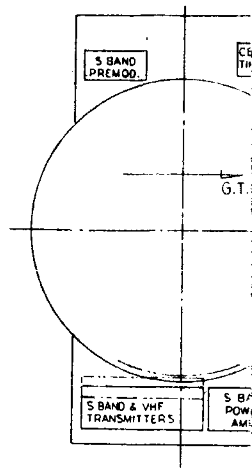

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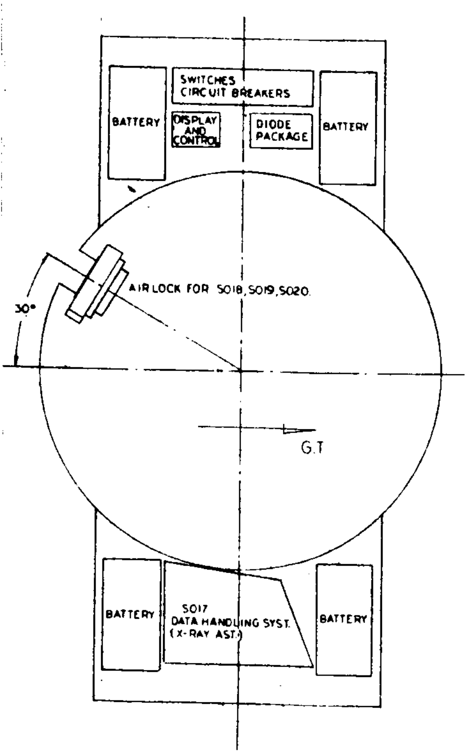

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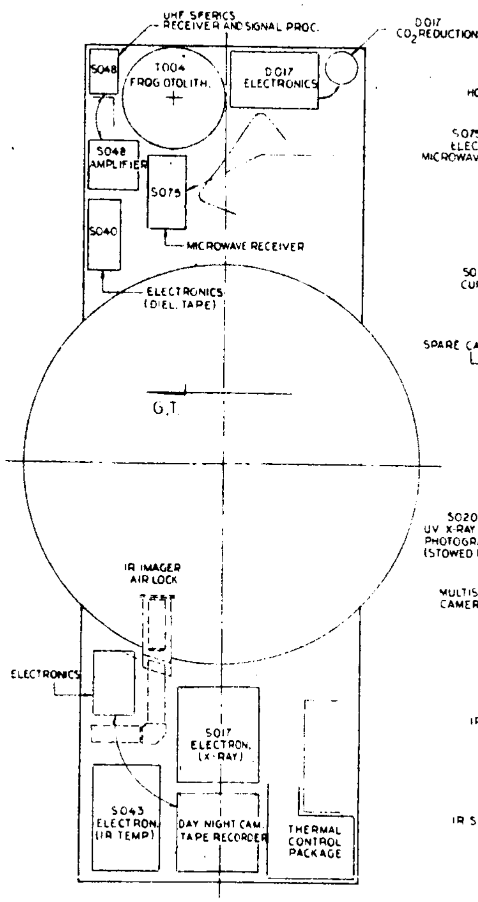
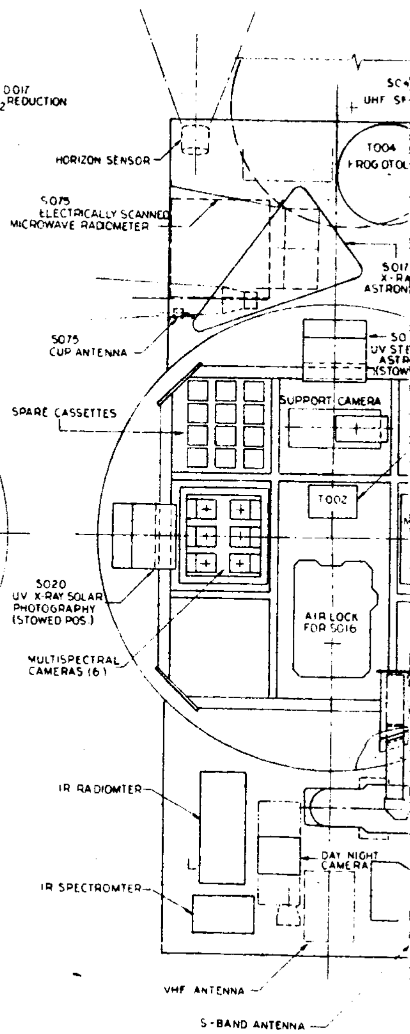
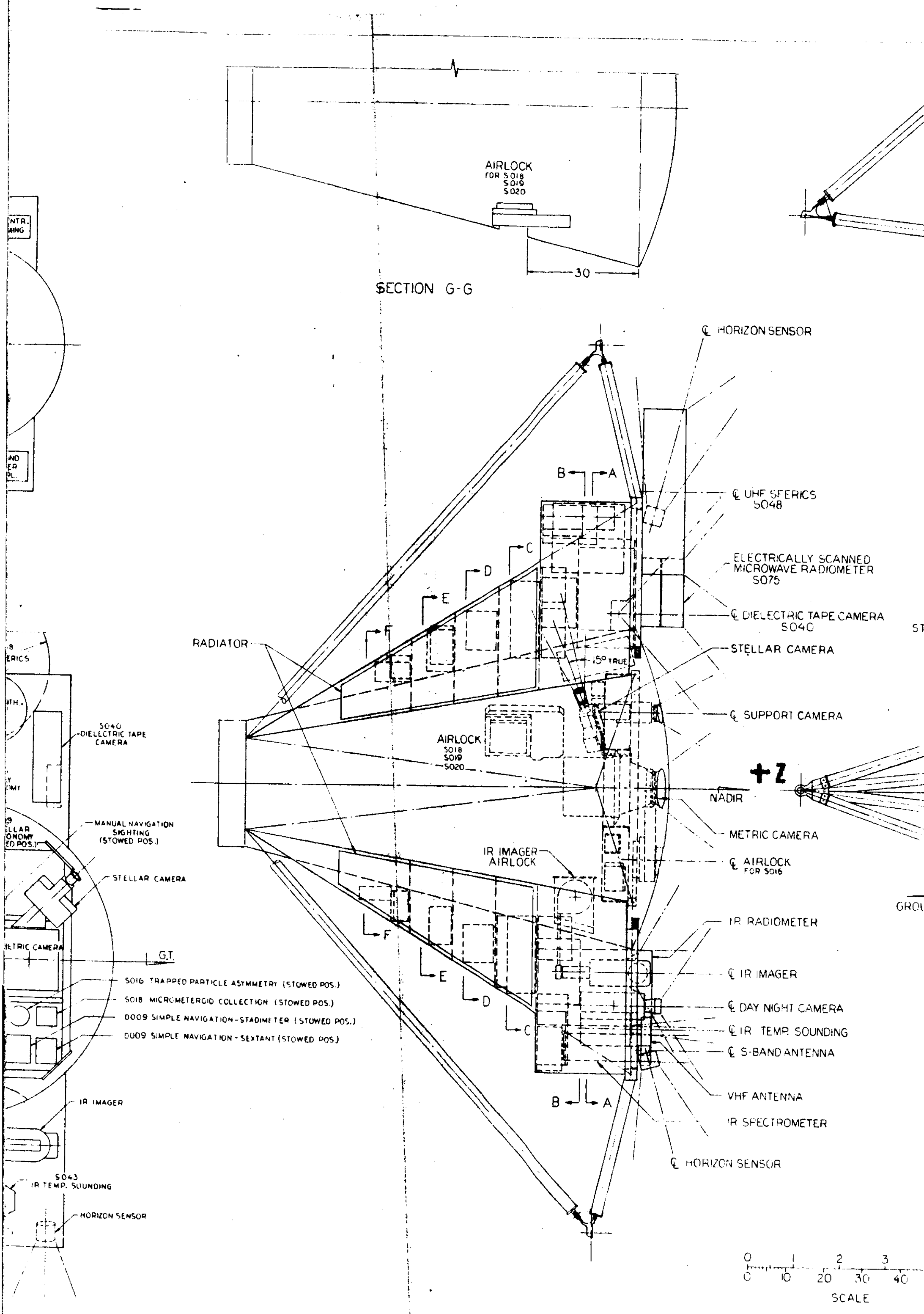


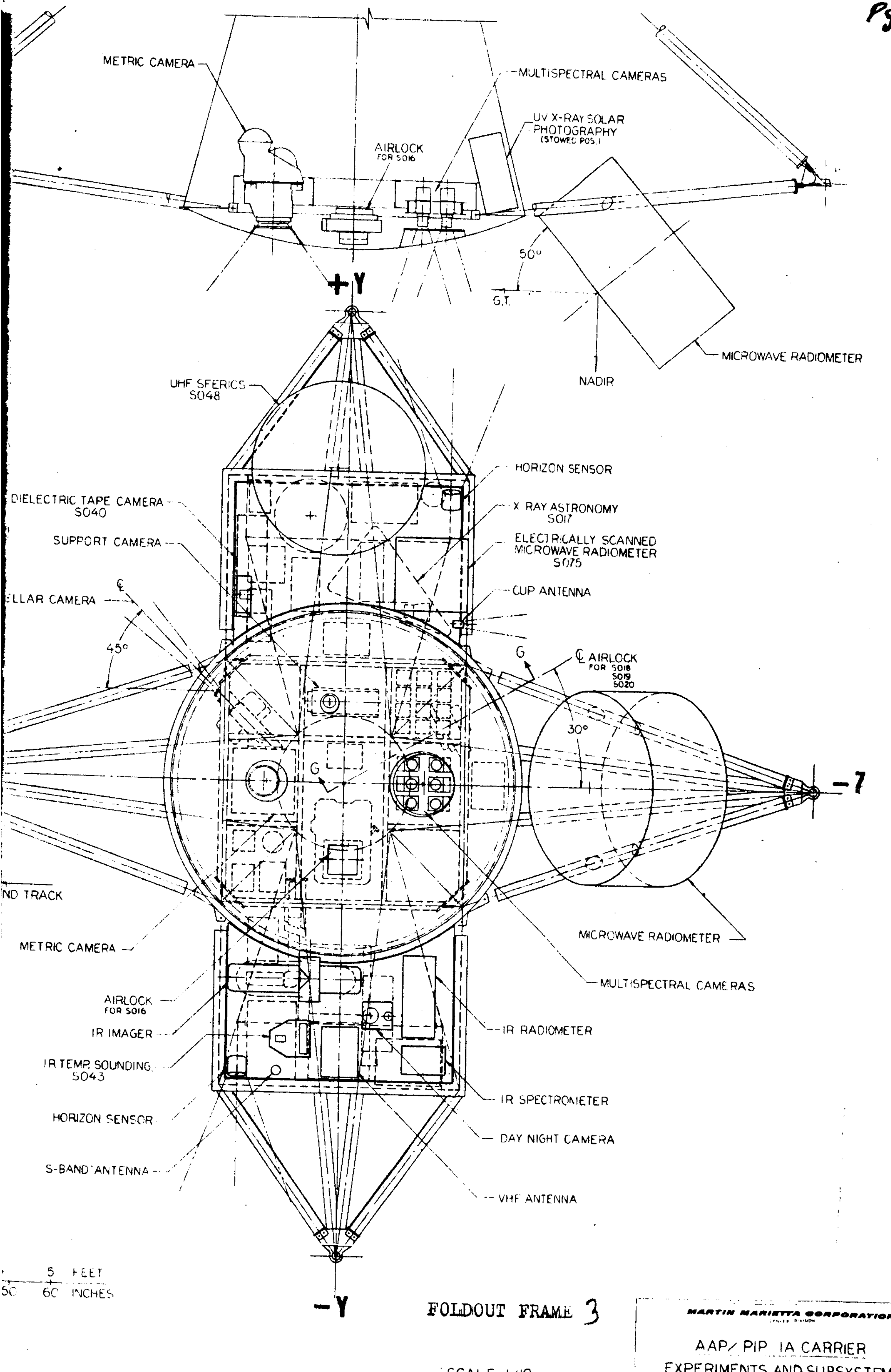
SECTION B-B



SECTION A-A



FOLDOUT FRAME 2



FOLDOUT FRAME 3

SCALE 1/10

MARTIN MARIETTA CORPORATION

AAP/ PIP IA CARRIER
EXPERIMENTS AND SUBSYSTEMS INSTALLATION

FIGURE 3

8.31.1967
R. SCHOFFEL

PR 29-39

TRADE STUDY REPORT

GROUND CHECKOUT SYSTEMS

AAP/PIP EARLY APPLICATIONS

Contract NAS 8-21004

7 September 1967

Prepared by:

Approved by:

MARTIN MARIETTA CORPORATION
DENVER DIVISION

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1. INTRODUCTION

A study was performed to identify and select an optimum Electrical/Electronic checkout method for the 1A Integrated Carrier.

To accomplish this task the Test Flow Chart was analyzed to determine specific requirements and limitations of both the Denver and KSC test sites. A functional matrix was then prepared to identify the major test requirements and to define potential design approaches.

Trade offs were conducted in areas of overall cost, checkout equipment delivery, schedule impact, and the ability of each method to fulfill the test requirements.

2. SUMMARY

As a result of the study, it has been determined that the Digital Test Set (DTS) with a Ground Power Distribution and Control System Ground Display and Control Panel, and miscellaneous laboratory type equipment will best satisfy the overall needs of the program. To minimize the total test time, it is required that the test and checkout be performed closed loop and independently of T/M Ground Station support. To accomplish this objective a limited PCM decommutator will be required to synchronize the DTS with the Data Management System. For those tests requiring open loop radiation, receivers, a tape recorder and some laboratory test equipment will be utilized. Existing T/M ground stations at Denver and KSC will be used on an "off-line" basis for data reduction purposes.

3. REQUIREMENTS

In general the Electrical and Electronic GSE shall provide a means of testing the Carrier to ensure that all systems are performing within the design specifications. Factors which must be considered in defining the 1A checkout system are the Basic Test Philosophy, time allocated, and specific requirements of the subsystems and experiments to be tested.

3.1 Test Philosophy - Since the primary purpose of the Carrier Mission is to collect and return experiment data, a thorough checkout and accurate calibration of the Data Management System (DMS) must be performed.

To fulfill this requirement the checkout GSE will commence testing at "black-box" level to ensure that each component of the total system is performing within its individual specification. Through this method, repetitive system data accuracy will be provided. The normal building block method will be employed wherein additional components are mated and tested until finally complete experiment/ DMS testing will have been performed.

The GSE shall also be capable of supporting Mission Simulation, EMI, Contingency and Thermal-Vacuum testing. In addition to providing electronics stimulus and a response measurement capability, the GSE may be required to provide a command and control function to mechanical GSE.

Testing will be performed at both Denver SATF, SSL, and at the KSC MSOB and LC-34. The expected sequence of testing is defined in PR-29-26 and PR 29-27.

Since the Carrier program consists of only one flight vehicle, the approach will utilize one set of checkout equipment at both test areas. Major advantages of utilizing a single set of equipment are (1) the inherent "debugging" of new equipment will be avoided and (2) a maximum level of testing continuity will be achieved.

3.2 Time Allocated - The checkout GSE must be defined, developed, manufactured, verified and installed within 6 months after program go-ahead.

3.3 Specific System Requirements - The Electrical/Electronic portion of the Carrier consists of; experiments, an Electrical Power Distribution system, a Guidance and Navigation system, a Thermal Control System,a Data Management System, a Thermal Control System, a Data Management System and an Astronaut Display and Control System.

Each of the subsystems will be described and their specific checkout requirements defined, where known:

3.3.1 Experiment - The Carrier checkout GSE must interface with the experiments and provide both stimulus and output data evaluation where applicable. The experiments and their associated checkout equipment will be obtained both GFE and CFE and delivery will occur at varying times throughout the testing. To supplement those experiments which will arrive late in the test phase, the GSE must provide accurate simulation for preliminary calibration.

Several of the experiments will provide a test connector, paralleling the operational connector, to assist in malfunction isolation. The Carrier checkout GSE shall interface with the test connector and integrate each experiment into the overall test flow.

The specific types and quantities of data received from the experiments and their associated housekeeping functions are defined in Report PR 29-44.

3.3.2 Electrical Power System - The Carrier power system will consist of several batteries supplying power to the airborne components through current shunts, diodes, circuit breakers and motor driven switches. The checkout GSE shall provide a means to ensure that the electrical system components are functioning within the rated specifications.

During those tests not requiring flight batteries, the GSE will provide a regulated, limit protected, ground power source to simulate the batteries. During mission simulation testing the GSE must provide a "floating", facility isolated power source to the carrier.

3.3.3 Guidance and Navigation - The Guidance and Navigation System (G&N) will contain horizon sensors in both the pitch and roll axis and a yaw axis gyro to maintain Carrier attitude. The Carrier G&N system will interface with the CSM Flight Controls to provide steering information for operation of the RCS jets. The GSE will be required to provide both electrical and physical stimulus to the components while evaluating the resultant outputs.

3.3.4 Thermal Control System - To maintain temperature control of the heat producing components, the Thermal Control system will employ several liquid cooled cold plates. A primary and a backup electric motor pump will circulate Freon 21 through the cold plates and then dissipate heat via a radiator. The Electrical GSE will be required to control, simulate, measure, and evaluate pressure and temperature sensor data.

During operation of the thermal control pumps the GSE must provide a means of continuously monitoring the system performance to determine shutdown criteria.

3.3.5 Data Management System - The Data Management System (DMS) is required to collect and transmit data in a time scheduled sequence, from both the experiments and the carrier subsystems. In general, for all components, the GSE is required to provide a precise stimulus signal at several discrete levels to each data input point, and to provide a measurement of the corresponding output signal at both component and system levels. Each component of the DMS and its attendant GSE requirements will be discussed individually:

3.3.5.1 Signal Conditioner - The Signal Conditioner receives data from the experiments and subsystems in 0-40 millivolt analog form, and 115V 400 cps, discrete functions in addition to a timing signal. The signal conditioner then supplies this data to the PCM encoder in 0-5 volt and 0-20 millivolt analog form for digitizing and transmittal to the ground. The GSE must provide precise step calibration signals for each input and to measure the resultant output.

3.3.5.2 Encoder - The PCM encoder will receive 0-20 millivolt and 0-5 volt analog signals, 0-32 volt parallel and several bilevels, and timing signals for digitizing and encoding at 5.12 kbs. GSE must provide several precise step calibration signals for each input and then decode the resultant pulse train for evaluation of each response to an input stimulus. Since the selected encoder is an 8 bit package, the stimulus and measurement devices must be capable of ± .1% accuracy of full scale.

3.3.5.3 Tape Recorders - The DMS tape recorder will receive data from the encoder in a 5.12 kbs serial pulse train. Upon receipt of a dump command the recorder will playback at a rate of 112 kbs. The experimenters will also supply two tape recorders for data collection and storage. Each recorder will receive data from at least two sources selected by the D&C panel operator.

The GSE shall be capable of stimulating the various tape inputs with similar data forms and shall provide a means of presenting the playback signal for evaluation. Checks will be made to verify Wow, flutter, tape speed and distortion.

3.3.5.4 Transmitters - The airborne system contains four RF transmitters installed in the carrier. The three VHF transmitters and the one S-band transmitter will receive data in either FM or pulse train form, with the duty cycles being controlled by the D&C panel operator.

Transmitter center frequency, deviation, power output and sideband energy tests will be accomplished by use of laboratory type test equipment.

3.3.5.5 Antenna System - The airborne antenna system will contain both VHF and S-band antennas and coax, and an RF diplexer for the three VHF transmitters. The GSE must verify VSWR, power losses, diplexer rejection, and radiated output. To minimize RF radiation scheduling problems, antenna hats and RF loads will be required.

3.3.5.6 Display and Control System - The Display and Control System is required for controlling power application to the carrier subsystems and experiments. The display function will be to monitor parameters necessary for experiment control. A part of the checkout GSE will be a display and control panel similar to the airborne unit which will be used for most of the ground testing. A checkout connector may be provided to test internal circuitry of the units before flight.

3.3.6 Total System Checkout - Upon completion of both the DMS components and individual experiment tests, a marriage/calibration will be performed. During this phase, the experiments and subsystems will be, where practical, exercised over their operating ranges and the resultant output levels noted.

3.3.6 (continued)

Several Ambient Level tests must be performed to determine drift characteristics and data repeatability. All systems will be in flight mode and responding to ambient conditions.

The most complex test to be performed is the Mission Simulation, wherein all systems will be exercised for varying periods of time. A Mission Simulation will be conducted with the carrier installed in the Thermal Vacuum Chamber.

To perform the Total Systems test, the GSE must be capable of stimulating the experiments and subsystems, where practical, determining the resultant output, and providing a means of verifying that all parameters are operating within their assigned tolerances. Capability shall also include the provisions for recording the real-time transmitted signal to facilitate post-test strip out and data analyses.

4. TECHNICAL APPROACH

The overall requirements of the GSE are to provide a stimulus to the carrier components and verify the response against anticipated tolerances. Since the majority of the GSE will be special purpose equipment and only six months is allocated from program go-ahead to installation, both a completely manual and an automatic checkout method have been considered.

In addition to the stimulus-response requirement, the GSE must be capable of simulating experiments and sensors in the event the components are not available.

The methods of checkout which have been evaluated will be described in three categories; (1) test and checkout, (2) power distribution and control, and (3) supporting groups.

A brief description of the approaches or ground rules considered for each category will be discussed:

4.1 <u>Test and Checkout System</u> - Three basic checkout systems were considered to be applicable for the carrier program:

a. Automatic Checkout Equipment (ACE)

b. Digital Test Set (DTS)

c. Manual Test Method

4.1 (continued)

A brief description of the overall functions of each system are:

4.1.1 Automatic Checkout Equipment (ACE) - The ACE is a highly complex computer based test and checkout system. The ACE is capable of testing a complete spacecraft down to the component level in addition to controlling the ground servicing and support equipment.

The ACE was developed for NASA to test the Apollo Command, Service and Lunar Excursion Module. Each ACE installation contains over 120 test racks and consoles, and are presently installed at North American, Grumman, and at the NASA Houston and Merrit Island facilities.

Tests are initiated by one of several console operators located in the control room. A central computer then selects the requested stimuli, routes it to the correct destination and returns the system response to the console for display. The ACE will display the resultant data in either analog or event form and will reproduce, on an alphanumeric CRT, up to 20 pages of computer memory stored data.

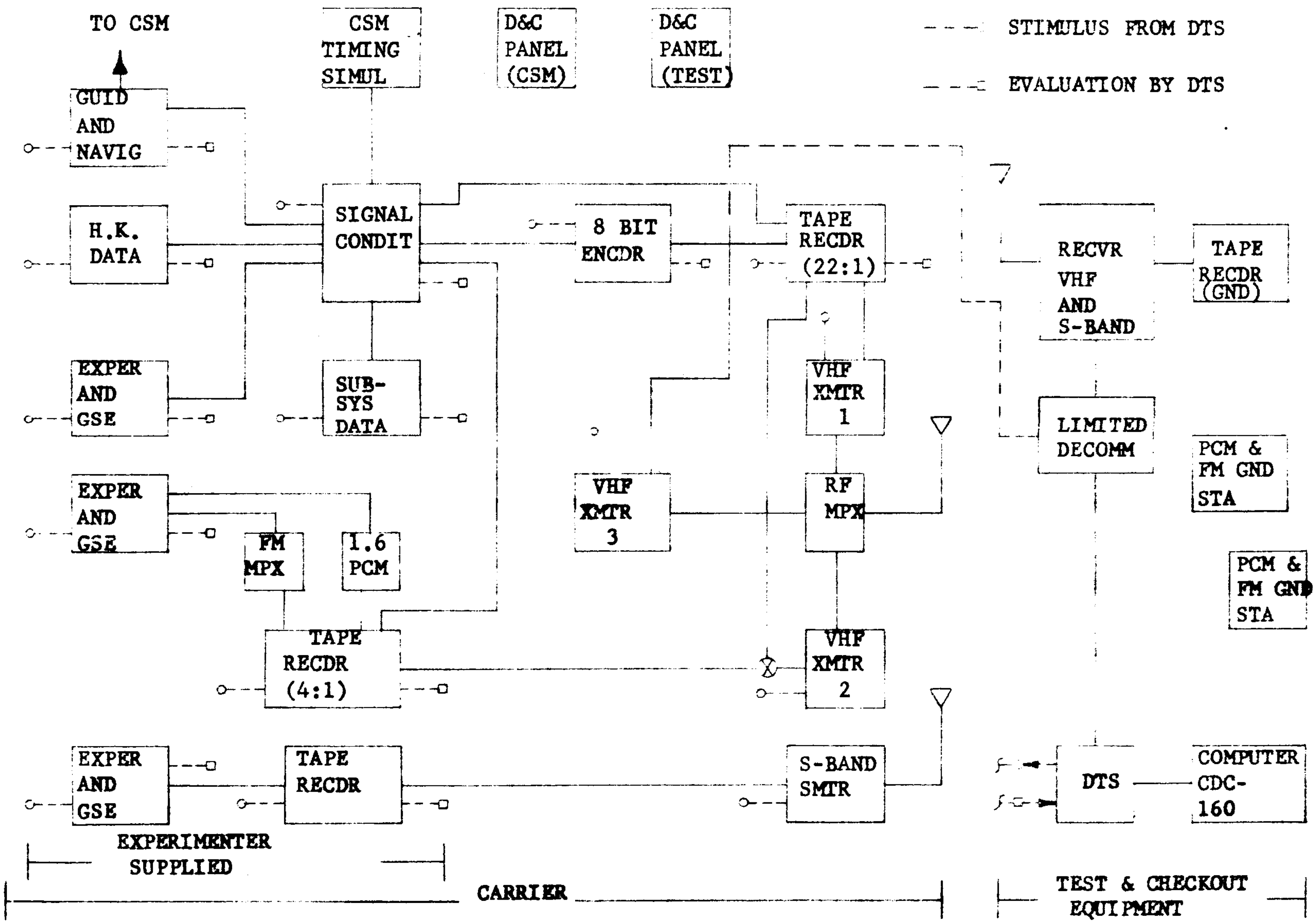
The ACE internally digitizes all analog and event responses into a 51.2 kbs PCM train, for processing within the main computer, since this is the primary bit rate for the Apollo spacecraft.

4.1.2 Digital Test Set (DTS) - The Digital Test Set (DTS) is an automatic test and checkout set which will provide a precise stimulus, measure the resultant output, and evaluate that output for adherence to specified tolerances. In addition it will perform switching and control functions.

The DTS was designed and developed by Martin Marietta Corp. for NASA-MSC under contract NAS 9-6630. The prototype is operational and scheduled for delivery to MSC.

The prototype DTS is packaged in two standard racks and connected to the airborne components through multi-conductor cables as indicated in Block Diagram Figure 4.1.2-1. Memory and control functions for the DTS are performed by use of a small computer and its peripheral software. Although the present DTS utilizes a CDC 160 computer, other computers such as Sigma 7 are compatible.

FIGURE 4.1.2-1
DIGITAL TEST SET (DTS)



4.1.2 (continued)

Basically the DTS will sequence a series of pre-stored operations, accomplish the necessary computations to analyze component or system performance, and then provide a visual indication of system status, all within a few seconds.

The DTS has three basic modes of operation; automatic, semi-automatic, and manual. In the automatic mode the complete test program is cycled through until the last test is completed. If a malfunction is detected, the system will automatically perform a group of tests to isolate the fault to a failed module, and then display all pertinent information.

The semi-automatic mode is similar to the automatic mode except that each test is initiated by the Test Engineer and displays pertinent data for that step.

In the manual mode, the Test Engineer may perform a single test, revise an existing test or design a new test. The DTS console contains a keyboard to allow writing of a program using Test Language Format, thereby eliminating the need for professional programmers.

The DTS will require the support of a limited decommutator to synchronize with the PCM pulse train. It is expected that a "hard wire" connection will be provided from the airborne encoder output to the limited decommutator to eliminate the necessity for open loop radiation during subsystem testing.

A highly desirable feature of the DTS is its capability to continuously sample and evaluate all system outputs with the system responding to ambient conditions to provide overall drift characteristics.

The computer logic is such that prior to applying stimulus to any airborne component a series of internal verifications are performed to ensure the correct destination and signal characteristics have been selected. In the event of an incorrect selection, the computer will halt and cause the DTS to indicate a malfunction. A series of automatic malfunction isolation tests may then be performed and the pertinent data displayed.

4.1.2 (continued)

Upon completion of testing at Denver, the computer memory may be transferred to magnetic or paper punch tape. This same tape can be used to load the memory of either the same or another computer at KSC in order to ensure continuity of testing.

A final acceptance test would be performed at both Denver and KSC wherein the DTS cabling is removed from all components, except the PCM encoder output and the ambient conditions evaluated.

To supplement those areas of test which are either not practical or economical for the DTS to perform, (VSWR, RF power checks, etc.) standard test equipment must be provided.

Documentation and formal test procedure requirements will be minimized since the Test Engineers programming sheets and the computer memory would provide the test parameters. Transfer of the data from the computer memory to paper or magnetic tape will eliminate the necessity of manually recording the many voltages and the high probability of introducing operator error, number transpositions, etc.

During the evaluation of DTS several inherent features, although not required for the original development contract, are readily available to minimize the carrier program requirements.

a. Connections from the DTS to components under test would normally be made with multi-conductor cables. Short adapter cables would be utilized to cross patch signal stimulus and output to the desired pin connections for the various components thereby requiring only a single set of long multi-conductor cable.

b. The test program would be oriented such that the components and system level tests would be verified by individual DTS programs thereby minimizing the memory and storage requirements of the computer.

c. Test records of measured parameters would be obtained from the computer memory to provide acceptance data.

4.1.3 Manual Checkout Method - The manual test and checkout method has been employed successfully on many programs. Although time consuming, highly accurate measurements can be obtained of component performance through employment of precision laboratory type equipment.

Test boxes providing access to each stimulus and measurement would be part of the GSE and located as shown in Block Diagram Figure 4.1.3-1. Each box would contain at least two test points for each parameter and a manual switch to either connect or isolate each component from the preceding component.

Test directions and instructions will be documented through use of formal test procedures. A typical sequence to be performed for each test point throughout the program would be:

a. Determine applicable test points from the procedure.

b. Adjust stimulus generator to the desired level and verify with a precision voltmeter.

c. Apply stimulus to the test point.

d. Determine applicable measurement test point from the procedure.

e. Read resultant output on precision voltmeter.

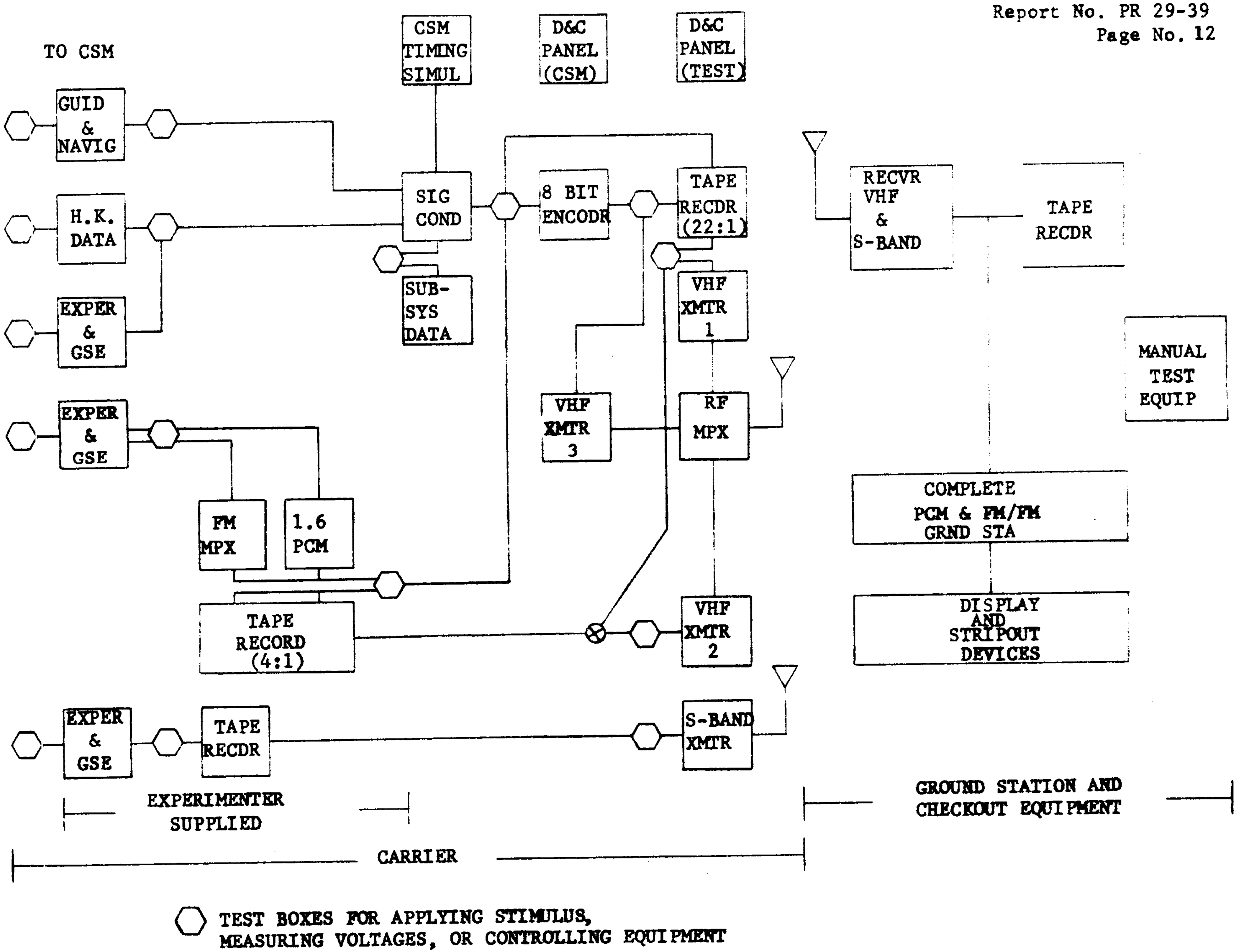
f. Verify the resultant output is within the specified tolerance and then record actual measured value.

Verification of the encoder will require real time decommutation and display support from a T/M Ground Station.

Availability of the test equipment will be influenced by the requirement for periodic calibration and accuracy verification and may require selected pieces of equipment for backup.

Upon completion of the component level tests a marriage/calibration will be performed with each experiment or subsystem being stimulated. All test equipment will then be removed and an RF open loop evaluation performed. In this mode all systems will be responding to ambient conditions while each data channel is evaluated in the T/M Ground Station.

FIGURE 4.1.3-1
MANUAL CHECKOUT METHOD



4.2 Power Distribution and Control - The airborne power source will consist of several batteries connected to buses in redundant combinations. The GSE must provide equivalent power sources to permit testing without utilizing the flight batteries.

The Titan program Power Distribution Control Rack (PDC) was initially considered as a ground power source, however, a detailed review of its capacity indicated it far exceeded the requirements of the carrier program.

A second, and more desirable method of supplying ground power is to obtain four, 28 volt 50 amp, commercial power supplies for rack installation. Each supply will be regulated and contain over/under voltage limit protection.

During mission simulation a bank of test support batteries will be utilized to electrically isolate the carrier from facility power.

A battery charger will be required to maintain the test support batteries and to prepare the flight batteries. A console used during the Titan series is applicable and contains a regulated N_2 source in the event the flight batteries require pressurization or purging.

4.3 Support Groups - To avoid schedule conflicts and test delays it is highly desirable that the test and checkout equipment be designed to operate independently. For the carrier program the major support group will be T/M Ground Stations at both Denver and KSC. Wherever possible, the GSE must interface on an "off-line" basis and only utilize the Ground Station support for tape playback, FM discrimination, data stripout, etc.

5. BASELINE SELECTION

The three major checkout methods, ACE, DTS, and Manual, have been summarized as to general capabilities as required by the carrier program (See Figure 5-1).

Although the ACE could readily satisfy the carrier program requirements, it was deleted as a candidate due to poor availability, high installation and programming costs, and a long lead installation time.

5. (continued)

The two remaining methods have been evaluated and can satisfy the needs of the program. Major items considered during the evaluation have been tabulated on both the DTS vs. Manual Checkout features chart (Fig. 5-2) and the GSE function/ Matrix forms.

As a result of the evaluation, the recommended approach is to utilize the DTS automatic checkout employing a limited decommutator, power distribution and control rack, receiver and tape recorder in addition to some laboratory test equipment. The inherent capability of the DTS to minimize checkout time, quickly repeat complete test sequences, and automatically perform malfunction localization are extremely valuable to a program which must interface with the Apollo systems. Several modifications will be required for the DTS, such as a more accurate stimulus generator and measurement units, provide for receiving a PCM decomm signal, add a multi-parameter display unit, and additional modules for input/output switching. Although the initial cost of the DTS is higher than that of manual test equipment, it is felt that its expense will be offset by the cost of the additional time and personnel required at Denver and KSC. Reliability and integrity of the test data will be greatly enhanced in the automatic method due to a minimum of operator functions being introduced. Overall, the flexibility of the DTS and its adaptability to future programs offer a potentially greater cost savings.

Areas such as antenna VSWR, transmitter characteristics and tape recorder playback quality are more practically and economically determined through use of manual test equipment. Items such as VSWR meters, signal generators, spectrum analyzers, etc., will be required to support these tests. With the availability of a limited decommutator schedule conflicts normally encountered, when time sharing equipment with other programs will be avoided.

A minimum of Telemetry Ground Station support will be necessary in some areas such as FM discrimination, data reduction and display. This is accomplished by recording test data at the output of a receiver, then playing back "off-line" through a ground station on a non-interfering basis.

In order to minimize the overall cost of a one flight program and yet provide the technical accuracies required, equipment selection will be determined in the following order:

FIGURE 5-1
GENERAL TEST CAPABILITIES

	ACE	DTS	MANUAL
Test Philosophy			
Flexibility	Good	Superior	Poor
Thoroughness	Good	Good	Good
Location			
Area Rqm'ts	Large Area	Minimal	Minimal
Special Rqm'ts	Air Condit.	Air Condit.	None
Relocation	Impractical	Good	Good
Time			
Initial Install	Very High	Low	Minimal
In Test	Low	Low	High
Cost			
Initial	Very High	High	Low
In Test	High	Low	High
Reliab. and Maint.	Good	Good	Poor
Personnel			
Number/Shift	4	4	7
Training Reqd.	Significant	Minimal	None
Systems Rqm't			
Accuracy	Very Good	Very Good	Excellent
Repeatability	Limited	Excellent	None
Monitoring	Limited	Excellent	None
Malf Localiz.	Limited	Excellent	Limited

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FIGURE 5-2
DTS VS. MANUAL CHECKOUT FEATURES

ITEM	DIGITAL TEST SET	MANUAL CHECKOUT
1. Time required to perform component, subsystem and system tests.	Complete test and evaluation performed in a few hours each for 5 test cycles.	Complete test may require in excess of 2 weeks each for 5 test cycles.
2. Test integrity-assurance that desired test specifications have been met.	Computer will perform all evaluations other than RF.	Human element may introduce errors in reading of meters, transcribing data, etc.
3. Test Data Accuracy	Stimulus and measurement units will be designed to meet program requirement.	Selection of laboratory type test equipment will determine overall accuracy.
4. Test Flexibility	Tests may be generated or modified at DTS keyboard after completing simple programming instruction sheet.	Test parameters may be modified by "red lining" test procedure, however, generating a new test will require writing detailed test steps, and then obtaining formal coverage.
5. Test Procedures	Basic program is prepared prior to commencement of test and modified thru use of computer worksheet. Recording of computer memory provides final documentation.	Basic test procedure is prepared prior to commencement of test, "red line" change is required to initiate "on-the-spot" changes and then documented by issuance of formal T.P. revisions

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FIGURE 5-2
(continued)

ITEM	DIGITAL TEST SET	MANUAL CHECKOUT
6. Ability to rerun tests	Tests will be reperformed at intervals from 2 seconds to 127 minutes for complete evaluation.	Only isolated "spot-checks" could be performed without incurring schedule delays.
7. Correlation of stimulus and resultant output measurement.	Evaluated within microseconds by DTS - Also automatic real time correlation of records.	Requires 2 or more people to simultaneously read and evaluate meters. Impractical to provide manual real time correlation of records.
8. Probability of detecting transient malfunction.	Very high due to continuous repetition of tests.	Very low since each data point is only verified one time during complete test.
9. Identification of transient malfunction.	DTS will indicate an "out-of-limit" condition and display all pertinent data noted at time of malfunction.	Technicians instantaneous observations will provide data.
10. Malfunction isolation.	DTS initially performs self test, and will then display all pertinent data for the malfunction to support technicians evaluation.	Technician will initially verify test equipment and connections, and then reperform test steps required to localize problem.

FIGURE 5-2
(continued)

	ITEM	DIGITAL TEST SET	MANUAL CHECKOUT
11.	Possibility of applying incorrect stimulus to component.	DTS will internally self verify each stimulus level and destination against stored program before applying voltage to component. If self-compliance is not received test will be halted.	Possibility of technician inadvertantly setting switches to incorrect position, grounding test leads or selecting adjacent test points.
12.	Test equipment self check and calibration.	Continuously performs self checking tests. A test tape could be provided as calibration standard.	Self check capability is minimal in manual test equipment. Standard test techniques would require check against another instrument of same accuracy. Requires periodic verification by calibration facility.
13.	Test crew size and qualification.	Special training to operate DTS. Computer language allows test engineer to write tests without requiring services of a professional programmer (A crew size of 2 engineers, 1 tech, 1 Q.C.)	Test requirements are within scope of average electronics technician (A crew size of two engineers, 3 techs, and 2 Q.C.)
14.	Continuous monitoring of critical parameters for drift characteristics.	Performed automatically without support of full T/M ground station.	Requires real time support of T/M ground station to supply decommutation, stripchart recorders and qualified personnel to evaluate records.

18

FIGURE 5-2
(continued)

ITEM	DIGITAL TEST SET	MANUAL CHECKOUT
15. Test Records	Computer memory will retain all pertinent data for the last test performed. Recording of data on tape will permit non-real time facilities usage for print-out in desired format.	Manually recorded data in test procedures will provide permanent record.
16. Test setup configuration control	Q.C. monitored computer program changes.	Q.C. monitored manual test lead hookup and test equipment adjustment.
17. Impact of test equipment malfunction	Partial or total stoppage of testing until repairs are made.	Partial stoppage of testing until substitute equipment is obtained.
18. Cost of testing	Initially high Low during test operations.	Initially low High during test operations.

19

5. (continued)

a. Government furnished surplus equipment

b. Utilization of available Martin Marietta equipment

c. Purchase of commercial test equipment

d. Manufacture of specialized existing test equipment

e. Design of new specialized test equipment

A cursory review of the NASA surplus facilities will be performed on a continuing basis as the airborne systems design is definitized. Inquiries will be made for example, as to prospects of obtaining and modifying the prototype DTS in lieu of a complete new build.

Included in the Appendix are Data Work sheets prepared during the GSE evaluation. The sheets will identify and describe major items of equipment to be utilized during test.

6. CONCLUSIONS AND RECOMMENDATIONS

In order to meet the accelerated carrier schedule and provide maximum test flexibility, an automated checkout system was selected. The system consists of the Digital Test Set, a limited decommutator, Power Distribution Console, Receivers, Tape Recorder and laboratory test equipment. It is recommended that, where possible, the above equipment be obtained GFP.

The Ground Station currently being installed at the Denver VTF facility, will satisfy the carrier PCM and FM requirements for both real time and off-line data collection, reduction and analyses. The NASA Gemini Ground Station currently located the KSC Hypergol 2 area can perform the same functions during system testing at KSC. It is recommended that the necessary efforts be undertaken to ensure availability of this equipment.

The majority of the experiment GSE will be provided by the experiment manufacturer and where necessary, will be utilized during system test. All electrical stimuli and status monitor interface requirements presently defined can be satisfied by the Digital Test Set. It is recommended that a continuing effort be performed to ensure that additional experiment requirements are integrated into the DTS capability.

6. (continued)

As the Guidance and Navigation system is further defined, the test requirements will be determined and integrated into the overall checkout approach. The horizon scanner and gyro system presently being considered can be tested by the DTS. It is recommended that a continuing effort be made to ensure compatibility of the DTS with the selected Guidance and Navigation system.

The airborne Gemini encoder is designed to accept low level input signals (0 to 20 millivolt). The noise and ripple content of the DTS stimulus and measurement will determine the test accuracies attainable. One approach to this problem would be to repackage both the stimulus generators and measurement units such that they would be located next to the airborne component, thereby minimizing noise pickup and line losses. A second approach would be the employment of line drive amplifiers to reduce the undesirable elements. It is recommended that the subject be further investigated to ensure the optimum test calibration.

MARTIN
DENVER

GROUND SUPPORT FUNCTIO

BY EBP DATE 8/21/67 SUBJECT Electrical SHEET NO. 1 OF

CHKD. BY DATE JOB NO.

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DE REQUIREMENTS		DES APPRO
SATF after electrical system pre power tests, MSOB, vacuum chamber, and LC-34	Verify functional performance of airborne subsystem components. 1) Data management subsystem A) Sig Cond Diff amps freq conv atten	Provide electrical stimulus inputs and measurements of 0.1%.		1) Digital test 2) Power supply Decade resis Input/output Signal gener Eput counter
	B) Encoder 108 0-5 VDC 96(191) 0-40MVDC 1 24-bit serial 32 bi-level parallel	Provide electrical stimulus inputs and read digital data of 0.1%.		1) Digital test limit decom 2) Input/output Voltmeter Power supply Ground stati
	C) Transmitting sys 1) Antenna	Provide for testing of antenna		Hats and term. Termaline power Signal generato Slotted line pi Isolator (S-ban VSWR meter (VH Parasitic horns to ground st Freq std or cou Coax and connec
	2) VHF transmitter	Provide for testing of VHF transmitter		Inline power me Voltmeters (2) Signal/Sq wave Ground station
	3) S-Band transmitter	Provide for testing of S-band transmitter		Power/DB meter Voltmeter (3) Freq std or cou Dummy loads Oscillator (app Ground station

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DEN 0664-36 (3-67)

N/EQUIPMENT MATRIX

IGN ACHES	COMPARISON OF APPROACHES: EXIST. EQUIP. NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	REMARKS
set		X					Digital test set	Mods req'd to DTS to improve accuracy
	X							
tance box	X							
test set					X			
ator								
/freq ind								
set		X					Digital test set	Mods needed to DTS to improve accuracy and accept PCM decomm input.
	X							
box					X			
	X							
(2)	X							May be offline with DTS
on								Must be on line for manual
loads					X			
meter	X							
r (S-Band								
VHF Band)	X							
ckup (S-band)	X							
d)	X							
band)	X							
/hard line								
ation	X							
nter	(c)X							
tors					X			
ter	X							
	X							
generator	(a)X							
					X			May be off line for all testing.
	X							
	X							
nter	(c)X							
	X							
rox 1 meg)	X							
								May be off line for all testing

MARTIN
DENVER

BY EBP DATE 8/22/67 SUBJECT Electrical SHEET NO. 2 OF
CHKD. BY DATE JOB NO.

GROUND SUPPORT FUNCTIO

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS		DESI APPROA
(continued)	D) Tape recorder	Provide for testing of tape recorders		Mode control tes Oscilloscope/plu Signal or sq wav Ground Station
	E) Constant band width unit	Provide for testing of constant band width unit		Input/output tes Voltmeter Oscilloscope/plu
	2) Power Distribution Subsystem			
	A) Battery supply	Provide a tester for the airborne batteries to 1) Verify battery heaters operation 2) Check pressure decay rate 3) Check voltage underload		1) Provide a bat test set as d TIIIM F10D01 2) Provide separ instruments
		Provide rechargable batteries and charger for flight simulation tests at 32 V max and 50 amp max		1) Utilize stan acid auto ba mounted in a test chart 2) Recharge air used in cont
		Provide variable ground power to airborne systems during test. 1) 24-33 volts dc 2) 50 amp		1) Utilize comm equipment 2) Develop/modi dist console
	B) Circuit Breakers	Provide for load currents to test CB.		Design load ban proper current
	C) Diodes	Check diode in battery circuit		Design diode te
	D) Motor Driven Switches	Provide means of activating transfer switches.		1) Utilize a re and control 2) Develop/modi dist console

FOLDOUT FRAME FOLDOUT FRAME

i/EQUIPMENT MATRIX

SIGN ...CHES	COMPARISON OF APPROACHES: EXIST. EQUIP. NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	REMARKS
t set					X		Use digital test set	
g in	(B)X							
e gen	(A)X							May be offline for all testing.
t set					X			
	X							
g in	(B)X							
tery load esigned for				X			Battery load test set	
ate test								
lard lead- teries suitable					X		Use airborne bat.	
borne bat site art.	X							
ercial	X						Commercial equip	Need interconnect.
fy power					X			
ks to provide					X			
ster					X			
mote display panel.				X			Remote display and control panel	
fy power .					X			

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MARTIN DENVER

GROUND SUPPORT FUNCTIO

BY EBP DATE 8/25/67 SUBJECT Electrical SHEET NO. 3 OF

CHKD. BY DATE JOB NO.

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS		DES APPRO
(continued)	E) Monitor bus voltage.	Provide a means to monitor and record bus profile, and provide over/under voltage protection.		Recorder and sen with audible/vis
	F) Inverter	Provide means of checking inverter. 1) Voltage amplitude 2) Frequency 3) Phase Rotation		1) Commercial eq 2) Digital test
	3) Display and Control Subsystem			
	A) Display and Control Panel	Provide a duplicate panel, ground design, to take the abuse of checkout		Use same design except to employ parts where poss in a rack or con breakout needed shooting. 1) Digital test monitor cable 2) Use manual te for trouble s
	B) Control and Distribution	No requirement from this unit.		
	4) Thermal Control Subsystem	No requirement from this sub-system except for the house-keeping sensor stimulation & monitoring of inputs to DMS.		
Denver and KSC	Mate with temp trans-ducers on carrier with landline instr.	Provide 10V power supply for transducer and recording device for approximately 55 temp transducers.		1) At thermal vac utilize exist 2) At all other equipment mu
KSC	Provide mods to GFE launch console to meet 1A carrier & experi-ment status			
NAA Downey	Provide 1A Carrier simulator	1) Provide simulated 1A load & signal characteristics to CSM		

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H/EQUIPMENT MATRIX

IGN ACHES	COMPARISON OF APPROACHES: EXIST. EQUIP. NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	REMARKS
isors ual alarm	X							Must be integrated into rack.
uip. set	X						Digital test set	
as airborne less costly ible. Mount sole; Cable for trouble set to breakout st equip hooting.							Digital test set	
uum chamber ting facilities facilities t be provided.								
								Dependent on specific req., remote D&C panel may fulfill need.

MARTIN
DENVER

GROUND SUPPORT FUNCTION

BY EBP DATE 8/28/67 SUBJECT Electrical SHEET NO. 4 OF
CHKD. BY DATE JOB NO.

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS		DESI APPROA
Houston	Provide Astronaut Trainer	Similar to D&C except does not req flight qualified components.		Build using groun components.
SATF (Final Mfg Step prior to Delvy to Test Facility)	Verify vehicle wiring harness continuity & insulation (Subsystem components installed, test mated, and then disconnected from harness for test)	GSE will: 1) Verify continuity of each independent circuit to each termination point. 2) Verify wire insulation exceeds breakdown voltage specification. 3) Tests to be repeated if major wiring modifications are made to vehicle.		A Automatic 1) Provides pre-p wire-to-wire a ground Hi Pot 2) Provides a pri record of GO/N output for eac B Manual 1) Requires manua cation using " stimulate each 2) Requires forma procedure to s test points ar ment readings.
SATF Pre-Power Application	Very electrical bus isolation meets specification.	GSE will: 1) Verify isolation of power buses		Manual 1) Using manual t ment determine between buses electrical gro 2) Requires manua of measured da verification a specified tole
Denver & KSC	Support Test Equip (sig gen, scopes, VTVM) etc.	To provide test equip during malf troubleshooting		Utilize standard equipment
	Reduce FM/FM SCO into individual data outputs	~~Provide FM discrimination~~ from either open loop or tape playback		Utilize standard equipment

FOLDOUT FRAME 1

FOLDOUT FRAME

DEN 0850A (8-67)

/EQUIPMENT MATRIX

...S N ...CHES	COMPARISON OF APPROACHES: EXIST. EQUIP. NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	REMARKS
d qualified								
rogrammed d wire-to- Test: ated O GO h step.		X					Has been included in facilities request by Mfg to use automatic (8-18-67)	**Disadvantages** A Automatic 1) Initial programming preparations & debugging are time consuming. 2) Requires specifically skilled personnel to prepare and operate. B Manual 1) Test time is lengthy 2) Possibility of operator error.
l verifi- 'megger" to circuit. l test pecify d docu-								
est equip- resistance and und. l recording ta and against rances.	X						Manual - using standard multimeters etc.	
test	X							Use one set of equip at all locations
grd station	X							Can be part of existing grd sta or obtain selected components.

MARTIN
DENVER

GROUND SUPPORT FUNCTI

BY AEH DATE 8/24/67 SUBJECT Electrical SHEET NO. 5 OF

CHKD. BY DATE JOB NO.

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS		DE APPR
Denver SATF KSC MSOB	Provide a CSM Simulator	1) 512 KC clock pulse 2) Data timing Gen		
Denver KSC	Provide EMI Monitor Circuits to Support EMI Testing.			

DEN 085038 (2-67)

FOLDOUT FRAME

FOLDOUT FRAME

ON/EQUIPMENT MATRIX

DESIGN APPROACHES	COMPARISON OF APPROACHES						RECOMMENDED APPROACH/EQUIPMENT	REMARKS
	EXIST. EQUIP. NO MOD.	ALT. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST		
					X			
					X		EMI pickup similar to TIII EMI mon circuits. No TPM's or DCI's required.	

FOLDOUT FRAME

FOLDOUT FRAME 2

ITEM NUMBER	NAME	QUANTITY DEN	QUANTITY KSC	FUNCTION	USAGE STATIONS
293201	Digital Test Set (DTS)	1	0	To provide the stimulus and measurements necessary to checkout the carrier subsystems and systems.	SATF, SSL, MSOB, LC-34
293203	Adapter Set-DTS to Experiments	1	0	Connects the DTS to the experiments and interfaces. Allows adapting unusual signal levels and format changes between DTS and experiments without requiring extensive changes to the DTS.	SATF, SSL, MSOB, LC-34
293204	Ground Power Supply and Distribution	1	0	Provides power for the airborne 28V buses during testing. Provides load banks for checking airborne circuit breakers. Provides undervoltage and overvoltage sensing and control of the airborne buses. Provides ground power to GSE where needed.	SATF, SSL, MSOB, LC-34
293207	Antenna Hats and RF Loads	1	0	Shields and loads carrier RF antenna systems.	SATF, MSOB, LC-34
293208	Ground Display and Control Panel	1	0	A panel identical in function to the airborne display and control panel which will be used in place of the airborne unit to take the abuse of the testing cycles.	SATF, SSL, MSOB, LC-34

FOLDOUT FRAME 1

FOLDOUT FRAME

GSE DATA SUMMARY SHEET

	DESCRIPTION	MODIFICATION DEFINITION	LEAD TIME (MONTHS)	PROBABLE SOURCE
	1. Two racks of electronic components. 2. CDC 160G computer. 3. Multiparameter display unit	1. Make stimulus more accurate (.1% of reading) and a range of 0-20 MV. 2. Make measurement more accurate (.1% of full scale) and a range of 0-20 MV. 3. Provide for PCM type data measurement. 4. Make program to accept PCM data. 5. Allow for 3 phase 200 VAC measurements. 6. Make mobile.	6 mos.	GFP NASA
	Cables, connectors, and electronic circuitry.		6 mos.	MMC
	1 Power supply 28 VDC 50 amps 1 Power supply variable 24-33 VDC 50 amps 1 power supply variable 24-33 VDC Resistor load banks 3 undervoltage sensors 3 overvoltage sensors		6 mos.	MMC
	4 Antenna hats (2 VHF, 2 S-band) 4 RF terminating loads (2 VHF, 2 S-band)		6 mos.	MMC
	Identical to airborne, except to use less costly ground qualified components.		6 mos.	MMC

FOLDOUT FRAME 2

FOLDOUT FRAME

ITEM NUMBER	NAME	QUANTITY DEN	QUANTITY KSC	FUNCTION	USAGE STATIONS
293209	Battery Load Test Set	1	0	This tester determines pressure decay rates and provides loading data. Also contains battery charger to charge the contractor site article airborne batteries for those tests requiring freedom from ground power.	SATF, SSL, MSOB, LC-34
293211	CSM Simulator	1	0	Functional simulator of all CSM subsystems that interface with the 1A carrier sub-systems and experiments. Used in place of the CSM at Denver and at KSC for system tests. 512 KC clock pulse, data time generator.	SATF, SSL, MSOB, LC-34
293215	Peculiar or Unique Experiment GSE	1	0	Checks out each experiment to the degree wanted by the P.I. & experiment contractor. NOTE: It may be possible for MMC to assume more of a check-out role with the DTS. This will have to be studied.	SATF, SSL, MSOB, LC-34
293216	Common Experiment GSE	1	0	Simulates or checks phenomena of two or more experiments.	SATF, SSL, MSOB, LC-34
293223	Receiver	1	0	Receives transmitted data from carrier transmitter.	SATF, SSL, MSOB, LC-34
293224	Tape Recorder	1	0	To record output of instrumentation receiver (pre-detection signals) for later data record and playback through a ground instr. station.	SATF, SSL, MSOB, LC-34

FOLDOUT FRAME /

FOLDOUT FRAME

GSE DATA SUMMARY SHEET

	DESCRIPTION	MODIFICATION DEFINITION	LEAD TIME (MONTHS)	PROBABLE SOURCE
	N_2 press regulator system, digital voltmeter, ammeter, shunts, recorder, power supply, resistor load bank.		6 mos.	MMC
	1 512 KC clock pulse generator 1 Data time generator		6 mos.	MMC
	Portable boxes and racks of electronic equipment and cables fabricated by each experiment contractor.		6 mos.	Experiment Contractors
	Commercial or lab experiment		6 mos.	MMC
	Standard T/M Receiver 2-Band and VHF		6 mos.	MMC
	Standard type small instrumentation tape recorder.		6 mos.	MMC

FOLDOUT FRAME 2

FOLDOUT FRAME

ITEM NUMBER	NAME	QUANTITY DEN	QUANTITY KSC	FUNCTION	USAGE STATIONS
293225	Limited Decommutation Station	1	0	Decommutates received data and presents data train sync pulses	SATF, SSL, MSOB, LC-34
293226	Diode Tester	1	0	To test the diodes in series with airborne batteries	SATF, SSL, MSOB, LC-34
293227	Interconnections	1	0	To interconnect GSE with facility, carrier, experiments, experiment GSE.	SATF, SSL, MSOB, LC-34
293228	Systems Test Equipment	1	0	To supply miscellaneous piece of commercial equipment & adapter sets necessary to check the airborne RF system	SATF, SSL, MSOB, LC-34
293229	Instrumentation System	0	1	This requirements data sheet identifies a KSC GFE program requirement. This system is needed to read & analyze data.	MSOB, LC-34
293230	Console Modification	0	1	This sheet identifies a KSC GFE program requirement changes to the main launch console are required to indicate 1A carrier & experiment status.	MSOB, LC-34

FOLDOUT FRAME 1

FOLDOUT FRA

GSE DATA SUMMARY SHEET

	DESCRIPTION	MODIFICATION DEFINITION	LEAD TIME (MONTHS)	PROBABLE SOURCE
	Two chassis of equipment		6 mos.	MMC
	Cables, connectors, one chassis of electronics.		6 mos.	MMC
	Interconnect 1) DTS with carrier and facility 2) Pwr Sup and distr with carrier, DTS and facility 3) Connect RF loads & antenna hats to grd. RCVR 4) Set of jumper cables for DTS checkout.		6 mos.	MMC
	1 Termaline power meter (S-band) 1 Termaline power meter (VHF) 1 Signal generator (S-band & VHF) 1 Signal/Sq wave generator (VHF) 1 Oscillator (1 megacycle) 1 Slotted line pickup (S-band) 1 Isolator (S-band) 1 VSWR meter (VHF) 1 Parasitic horn (VHF) 1 Parasitic horn (S-band) 1 Freq std or counter (VHF) 1 Freq std or counter (S-band) 1 Inline power meter (VHF) 2 DC precision voltmeter 1 True RMS voltmeter 2 Dummy loads (S-band) 1 Oscilloscope/plugins bat operated 2 Adapter sets (switches on cable breakout boxes) 1 Set adapter cables		6 mos.	MMC/GFE
			9 mos.	GFE
			9 mos.	GFE

ITEM NUMBER	NAME	QUANTITY DEN	QUANTITY KSC	FUNCTION	USAGE STATIONS	
293231	Data Reduction	1	0	This requirement data sheet identifies a Denver program requirement to use the Denver central data reduction facilities for test data analysis.	SATF, SSL	

FOLDOUT FRAME

FOLDOUT FRAME

GSE DATA SUMMARY SHEET

	DESCRIPTION	MODIFICATION DEFINITION	LEAD TIME (MONTHS)	PROBABLE SOURCE
			6 mos.	MMC/GFE

FOLDOUT FRAME 2

FOLDOUT FRAME

PR 29-40

TRADE STUDY REPORT

1A CARRIER HANDLING, ACCESS AND TRANSPORTATION EVALUATION

AAP/PIP EARLY APPLICATIONS

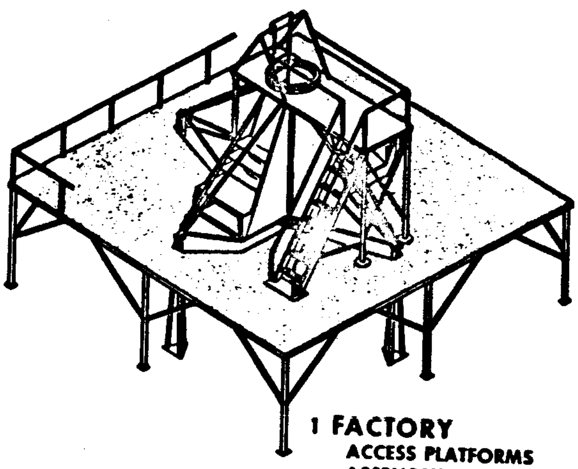
Contract NAS 8-21004

September 1967

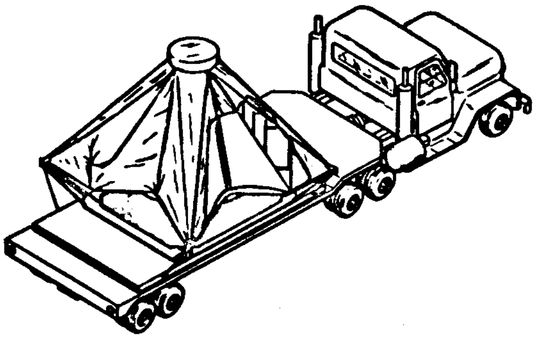
Prepared by: J. Worman

Approved by: D. Callahan

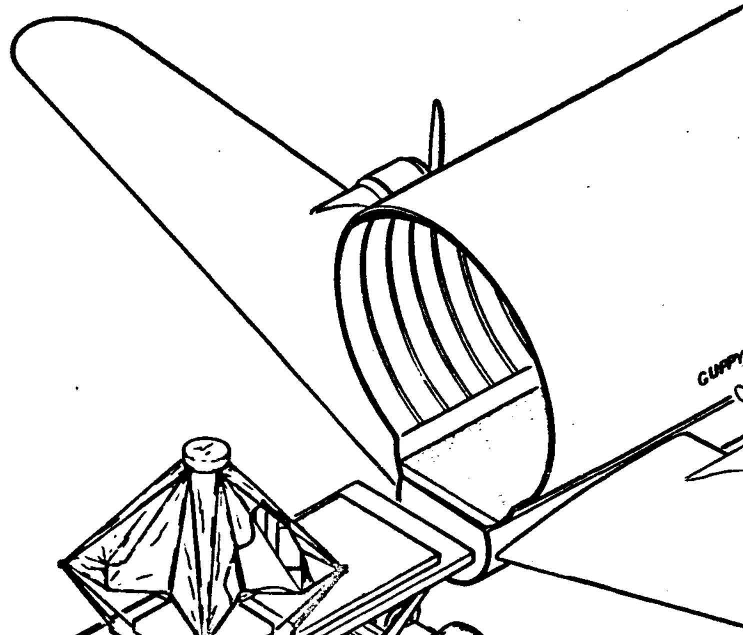
MARTIN MARIETTA CORPORATION
DENVER DIVISION

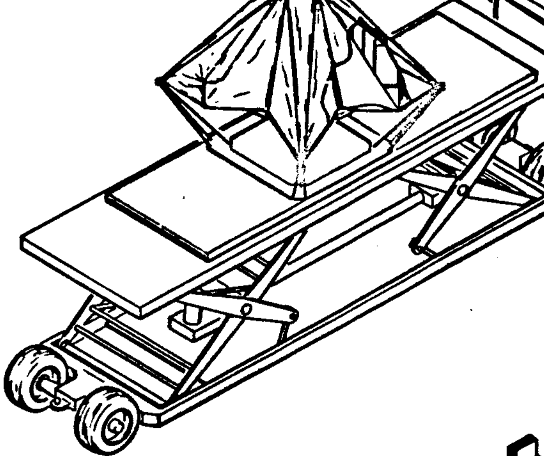


1 FACTORY
ACCESS PLATFORMS
ASSEMBLY FIXTURE
TRANSIT/COLLIMATOR
EXP. GRIPS & SLING SET

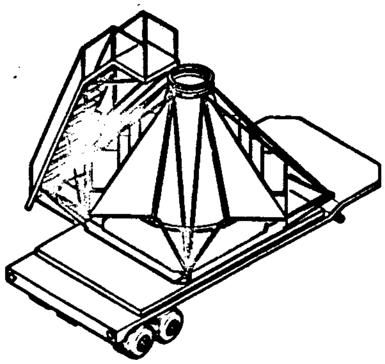


2 LOCAL TRANSPORT
SEMI-TRAILER AND TRACTOR TRUCK
TRANSPORT BASE
TIEDOWN KIT
PROTECTIVE COVER

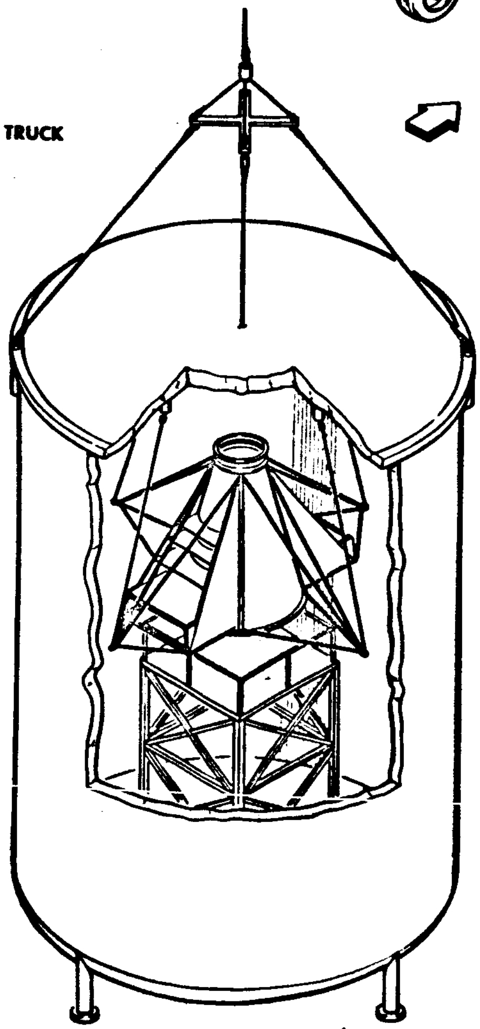




4 AIR TRANSPORT
LOADING TRAILER
CARGO TIEDOWN
BREATHER KIT



5 MSOB R & I
MOBILE ACCESS PLATFORM
MOBILE WORK STAND
TRANSPORT BASE
SEMI-TRAILER



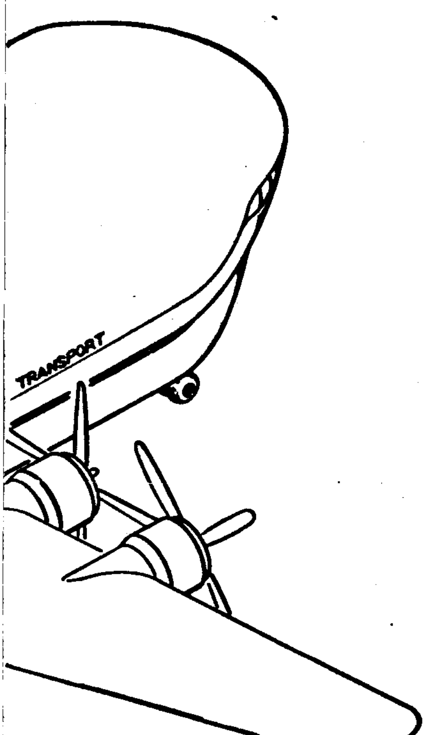
3 SPACE SIMULATION LAB
SLING SET
ACCESS PLATFORM
CHAMBER SUSPENSION SYSTEM

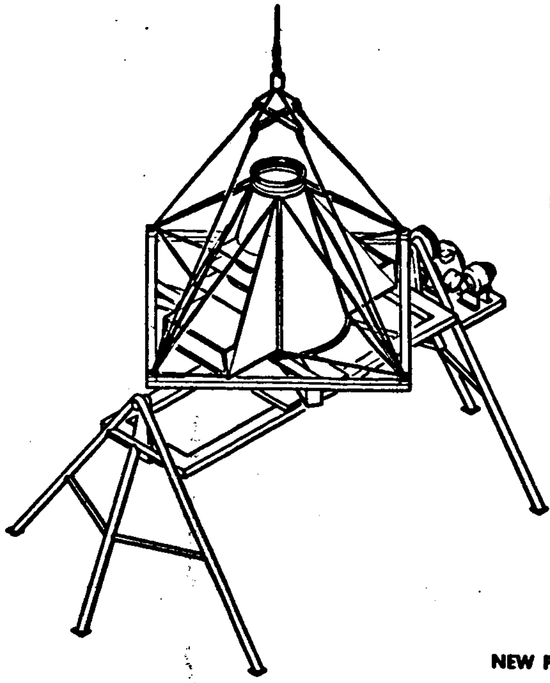
7 DOCK TEST
BRIDGE CRANE
SLING SET
ROTATION FIXTURE
CHAMBER INTERNA

FOLDOUT FRAME 1

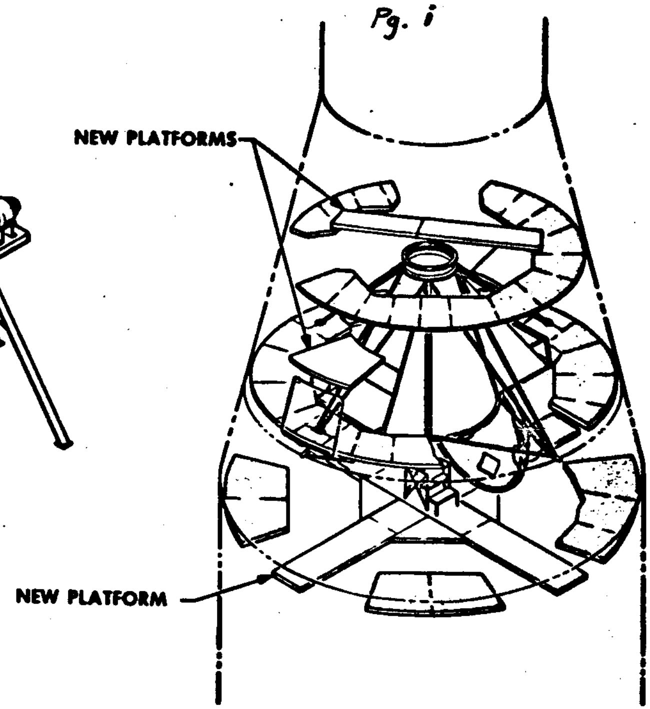
FOLDOUT FRAME

GROUND HANDLING, ACCESS A

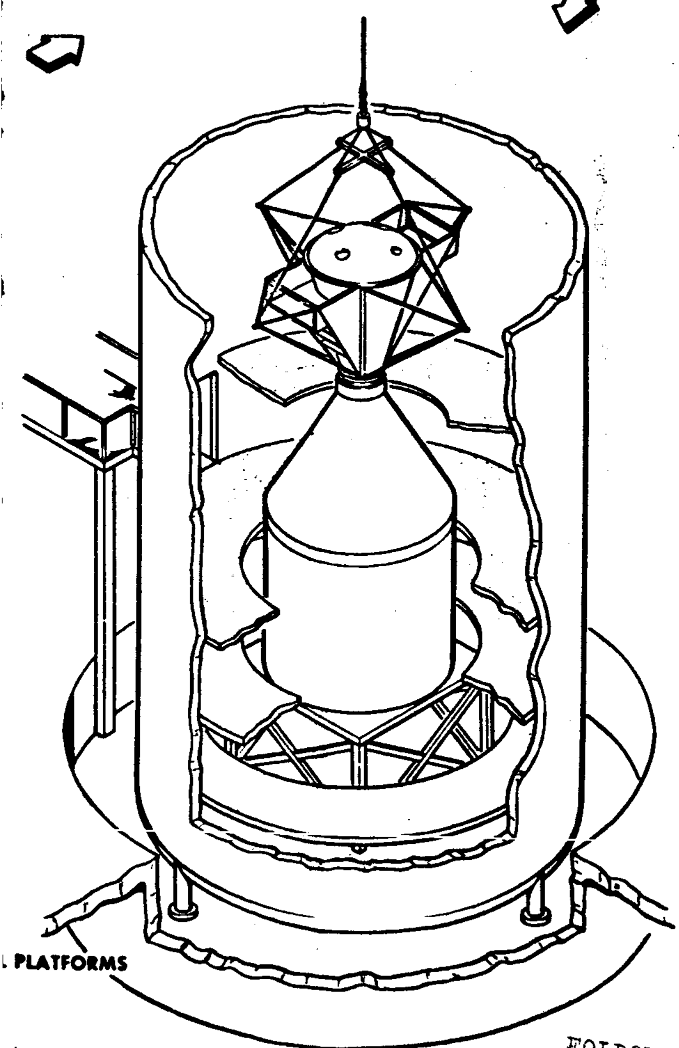


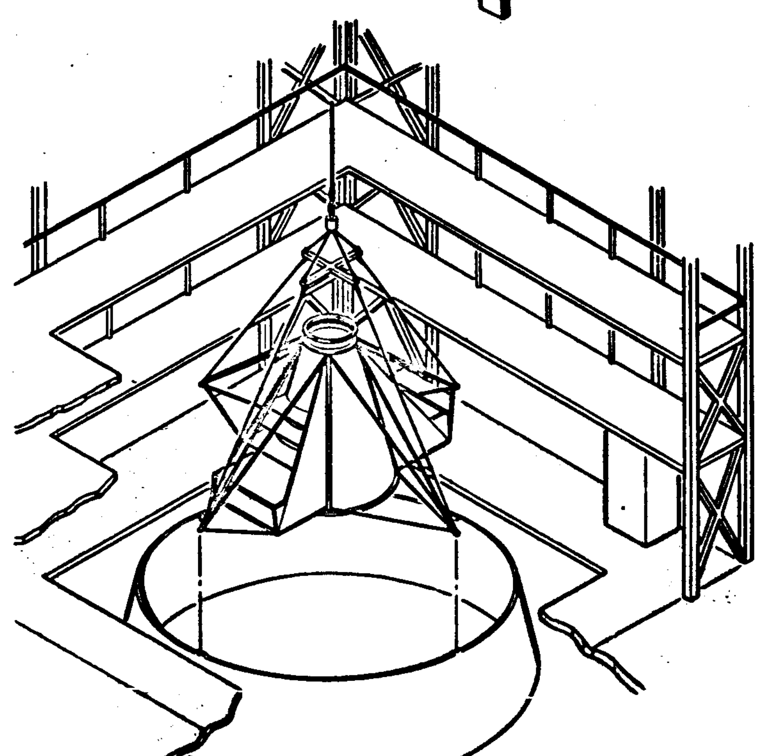


• CLEANING
BRIDGE CRANE
SLING SET
CLEANING POSITIONER AND ADAPTER
MOBILE ACCESS PLATFORMS



• INTERNAL SLA ACCESS
SLA INT. ACCESS PLAT. SET
DOCKING PORT TUNNEL LADDER
BATTERY INSTALLATION KIT
EXP. GRIPS & SLING SET
AUXILIARY WORK STAND SET
DOME HANDLING SET





• S/C BUILDUP
SLING SET
TAG LINES
ATTACHMENT KIT

FOLDOUT FRAME 2

FOLDOUT FRAME

ND TRANSPORTATION SYSTEMS

TABLE OF CONTENTS

FIGURES AND TABLES

1. INTRODUCTION

1.1 Purpose - The purpose of this study was to identify the handling, access and transportation requirements associated with 1A carrier operations, and to identify the equipment needed to meet the requirements.

1.2 Objectives - The objectives of this evaluation were to:

a. Provide a baseline configuration for 1A carrier handling, access and transportation.

b. Identify items in these categories which could have a major impact on cost and/or schedule.

c. Provide the data necessary to scope the Phase D Engineering and Manufacturing effort.

2. SUMMARY

A functional matrix was developed, a handling and transporation flow diagram was generated, trade studies were performed and an end item GSE list was prepared. Items to be provided both as CFE and GFE were identified.

Costs were established for engineering, manufacture and materials for new-design new-build and modification to existing equipment.

Layouts were prepared to:

a. Determine those modifications to the basic NAA LM platform set required to provide SLA internal access where the carrier is a part of the spacecraft on the launch pad.

b. Determine modifications required to the NAA Cleaning Positioner to facilitate final cleaning of the Integrated carrier (with trusses attached).

c. Determine the method of supporting the 1A carrier in the Pregnant Guppy Aircraft during shipment from Denver to KSC.

The approaches selected are compatible with existing mainline Apollo operations and with IA program schedules. Costs have been minimized by using existing Apollo equipment where practicable.

3. HANDLING, ACCESS AND TRANSPORTATION ANALYSES

3.1 Requirements

a. Handling, access and transportation equipment must be provided to:

Support movement of the carrier between the Spacecraft Assembly and Test Facility (SATF) and the Space Simulation Laboratory (SSL), from the Denver plant to the airport, from the KSC skidstrip to the MSO Building, between the MSO Building and the PIB, and finally to LC 34.

Facilitate access to the integrated carrier during subsystem and system tests in the SATF, SSL, MSO Building, and LC 34.

Provide access to the SLA/1A carrier (1) during the fit check in the MSO Building EIS, (2) when the carrier and SLA are mated for spacecraft build-up, and (3) during launch complex test and service operations.

Facilitate site and flight article ground support during structural test, compliance tests, subassembly and experiments installation.

Support weight and balance activities.

Facilitate carrier rotation to horizontal and inverted attitudes.

Support final cleaning operation.

Support Denver pack and ship activities.

b. The carrier transport base must be designed to interface with the Pregnant Guppy general cargo pallet.

c. The GSE shall impose a minimum of new facility and support requirements on KSC ground operations and utilize existing Apollo line GSE to the greatest extent possible.

3.2 Approach - In conducting this study, the following approach was used:

a. Using the Denver and KSC ground operations flow as spelled out in PR 29-26, Study Report, Flight Article and GSE Acceptance, and PR 29-27, Study Report, KSC Ground Operations Plan,as a baseline, a handling, access and transportation sequence was developed (see Figures 1 and 2).

b. From this sequence, individual requirements were derived, technical approaches to meet these requirements were conceived, trade-offs between candidate approaches were conducted, and finally, GSE end items capable of meeting individual requirements were identified. The results of this logic are presented in matrix form in Appendix A, Table A-I.

c. Data sheets were developed to present that data necessary for cost analysis and existing equipment survey. These data sheets include a description of the item, quantity, function, usage stations, criticality category, design category, lead time and probable source. The results of this logic are presented in Appendix A, Table A-II.

d. The equipment selection process made maximum utilization of existing Apollo line GSE.

1A CARRIER HANDLING & TRANSPORTATION

GPL

STRUCTURES LAB

CARRIER MOUNTED IN "LOAD TEST" FIXTURE

LOAD CARRIER STRUCTURE ONTO SEMITRAILER

STEPS:

1. HOIST CARRIER STRUCTURE AND INSTALL IT ON TRANSPORT BASE
2. HOIST CARRIER STRUCTURE AND TRANSPORT BASE AND LOAD ONTO SEMI-TRAILER

EQUIPMENT

BRIDGE CRANE
SLING SET
TRAILER TIEDOWN GEAR
TRANSPORT BASE
HYDRA-SET (5-TON)
ACCESS PLATFORMS
SEMI-TRAILER &
TRACTOR TRUCK

INTRA-PLANT ROAD

TRANSPORT OF CARRIER STRUCTURE TO SATF

(SEMI-TRAILER & TRACTOR TRUCK)

HIGH BAY AREA

CARRIER STRUCTURE IN VERTICAL ASSEMBLY FIXTURE

INSTALL SUB-SYSTEMS & SUB-SYSTEM C/O

-INSTALL COMPONENTS & SUB
-SUBSYSTEM FUNCTIONAL TES

STEPS:

1. HOIST CARRIER STRUCTUR FROM SEMI-TRAILER
2. INSTALL CARRIER STRUCT ON SUPPORT FIXTURE
3. INSTALL SUB-SYSTEMS

EQUIPMENT:

BRIDGE CRANE
SLING SET (FOR CARRIER
AND SUB-SYSTEM COMPONE
HYDRA-SET (5-TON)
HOISTING TRAY
ACCESS PLATFORM, B-1
WORK STANDS, MOBILE
PLATFORM TRUCK
SEMI-TRAILER & TRACTOR
ATTACHMENT KIT

SATF

MOVEMENT OF CARRIER TO WEIGHT AND BALANCE AREA

CARRIER IN VERTICAL ATTITUDE

EQUIPMENT:

BRIDGE CRANE
SLING SET
HYDRA-SET (5-TON)
TAG LINES

WEIGHT & BALANCE AREA

CARRIER IN WEIGHT AND BALANCE FIXTURE

WEIGHT & C.G. DETERMINATION

STEPS:

1. INSTALL CARRIER IN VERTICAL ATTITUDE ON MASS PROPERTIES FIXTURE
2. ROTATE CARRIER AND INSTALL ON MASS PROPERTIES FIXTURE IN HORIZONTAL ATTITUDE
3. REMOVE CARRIER FROM FIXTURE & ROTATE TO VERTICAL ATTITUDE

EQUIPMENT:

BRIDGE CRANE
SLING SET
HYDRA-SET (5-TON)
TAG LINES
WORK STANDS, MOBILE
ROTATION FIXTURE
MASS PROPERTIES FIXTURE SET
EXPERIMENT MASS SIMULATOR SET

MOVEM
CARR
& SH
BRID

FOLDOUT FRAME 1

FLOW DIAGRAM - DENVER

SATF

FLOW BASED ON AVAILABILITY OF ALL EXPERIMENTS AT DENVER

HIGH BAY AREA

CARRIER IN VERTICAL ASSEMBLY FIXTURE

OR

CARRIER IN VERTICAL ASSEMBLY FIXTURE

INTRA-PLANT ROAD

MOVEMENT OF CARRIE TO SPACE SIMULATIO LABORATORY

SEMI-TRAILER & TRACT

SYSTEMS
TS

E

URE

NTS)

TRUCK

EXPERIMENT INSTALLATION

- INSTALL AVAILABLE EXPERIMENTS
- INSTALL SIMULATORS FOR THOSE NOT AVAILABLE
- ALIGN EXPERIMENTS
- INSTALLATION TEST

STEPS:

1. INSTALL EXPERIMENTS AND SIMULATORS
2. ALIGN THE FOLLOWING EXPERIMENTS:
   MULTI-SPECTRAL CAMERA
   METRIC CAMERA
   IR RADIOMETER/SPECTROMETER
   IR TEMP SOUNDING
   UHF SFERICS
   MICROWAVE RADIOMETER
   IR IMAGER
   MICROWAVE RADIOMETER
   SUPPORT CAMERA

EQUIPMENT:

EXPERIMENT GRIPS, AND SLING SET
SIMULATORS
WORK STANDS, MOBILE
TRANSIT/COLLIMATOR ALIGNMENT KIT
HOISTING TRAY
PLATFORM TRUCK
SIMULATOR HANDLING & INSTALLATION SET

INTEGRATED SYSTEMS TEST (FUNCT)

- ALIGNMENT VERIFICATION
- MISSION SIMULATION
- ECS PERFORMANCE TEST
- QUALITY SURVEILLANCE

CLEANING

LOAD CARRIER ONTO SEMI-TRAILER

STEPS:

1. HOIST CARRIER AND INSTALL IT ON TRANSPORT BASE
2. HOIST CARRIER AND TRANSPORT BASE AND LOAD ONTO SEMI-TRAILER

EQUIPMENT:

BRIDGE CRANE
SLING SET
TRAILER TIEDOWN GEAR
TRANSPORT BASE
HYDRA-SET
WORK STANDS, MOBILE
PROTECTIVE COVER

FLOW BASED ON PARTIAL AVAILABILITY OF EXPERIMENTS AT DEN

AND

IENT OF ER TO PACK P AREA BY E CRANE

PACK & SHIP AREA

CARRIER ON SUPPORT BASE

HIGHWAY TO DENVER AIRPORT

TRANSPORT OF CARRIER TO AIRPORT

SEMI-TRAILER & TRACTOR TRUCK

- REMOVE SELECTED ITEMS, EXPERIMENTS & SIMULATORS
- FINAL INSPECTION
- PACKAGE

STEPS:

1. INSTALL CARRIER ON SUPPORT BASE
2. REMOVE SELECTED ITEMS
3. INSPECT
4. PACKAGE FOR SHIPMENT
5. LOAD TRANSPORT BASE ONTO SEMI-TRAILER
6. LOAD CARRIER ONTO TRANSPORT BASE & INSTALL BREATHER & PROTECTIVE COVER

EQUIPMENT:

BRIDGE CRANE
SLING SET
EXPERIMENT GRIPS AND SLING SET
HYDRA-SET (5-TON)
SUPPORT BASE
TRANSPORT BASE
ACCESS PLATFORM SET
WORK STANDS, MOBILE
TRAILER TIEDOWN GEAR
PROTECTIVE COVER
BREATHER
ATTACHMENT KIT
HOISTING TRAY
PLATFORM TRUCK

FOLDOUT FRAME 2

R
N

)R TRUCK

SSL/AIR LOCK

CARRIER ON
SEMI-TRAILER

INSPECT CARRIER AND
PREPARE FOR REMOVAL

MOVEMENT OF CARRIER TO
CHAMBER TEST PREP
AREA BY BRIDGE CRANE

EQUIPMENT:

SUPPORT BASE,
SLING SET, ETC.

VACUUM CHAMBER

CARRIER SUSPENDED
IN CHAMBER

INTEGRATED SYSTEMS TEST (ENVIR)

-REF. MISSION PROFILE
-LEAK TEST
-TCS PERFORMANCE TEST
-QUALITY SURVEILLANCE

EQUIPMENT:

CABLE SUSPENSION SET
INTERNAL PLATFORMS

MO
TO
BR

IVER

DENVER AIRPORT

PREGNANT GUPPY
LOADING OPERATION

LOAD CARRIER ABOARD A/C

STEPS:

1. HOIST CARRIER AND TRANSPORT BASE AND LOAD ONTO LOADING TRAILER
2. POSITION LOADING TRAILER FOR A/C LOADING
3. ROLL ON CARRIER INTO CARGO COMPT EMPLOYING A/C'S PALLET & TIE DOWN
4. LOAD ANCILLARY SHIPPING CONTAINERS & TIE DOWN

EQUIPMENT:

MOBILE CRANE
SLING SET
HYDRA-SET (5-TON)
TRANSPORT BASE
ACCESS PLATFORM
LOADING TRAILER
TRANSPORTATION KIT
A/C PALLET

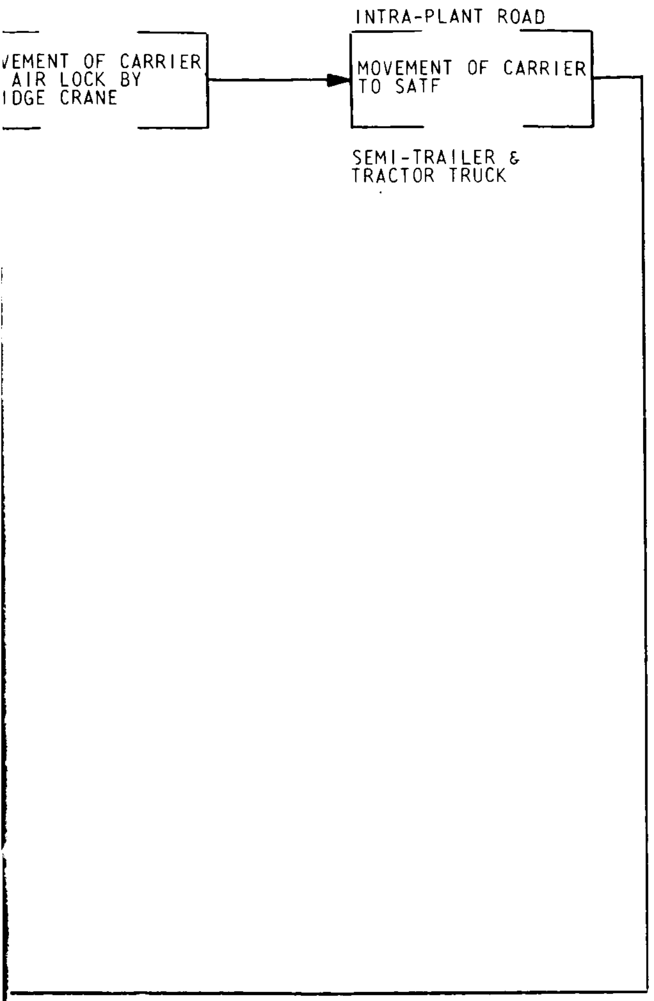
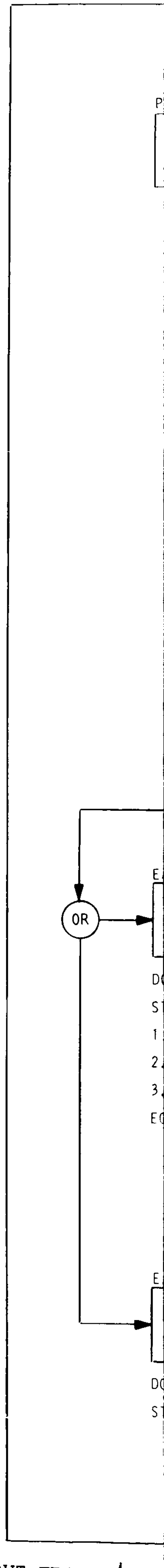


FIGURE I HANDLING AND TRANSPORTATION FLOW DIAGRAM - DENVER

FOLDOUT FRAME 4



FOLDOUT FRAME 1

REGNANT GUPPY A/C

AIRLIFT TO KSC

KSC SKID STRIP

PREGNANT GUPPY UNLOADING OPERATION

STEPS:

1. REMOVE CARGO TIEDOWNS
2. ROLL OUT CARRIER ONTO LOADING PLATFORM
3. HOIST CARRIER & TRANSPORT BASE AND LOAD ONTO SEMI-TRAILER
4. REMOVE TIEDOWNS & UNLOAD ANCILLARY SHIPPING CONTAINERS

EQUIPMENT:

MOBILE CRANE
SLING SET
HYDRA-SET (5-TON)
TRANSPORT BASE
ACCESS PLATFORM
LOADING TRAILER
TRAILER TIEDOWN GEAR
PROTECTIVE COVER
TAG LINES
BREATHER
SEMI-TRAILER & TRACTOR TRUCK

OVER THE ROAD

TRANSPORT OF CARRIER TO NASA INDUSTRIAL AREA

SEMI-TRAILER & TRACTOR TRUCK

LOW BAY AREA

CARRIER ON SEMI-TRAILER

RECEIVING & INSPEC

STEPS:

1. POSITION SEMI-T IN LOW BAY NEAR
2. REMOVE PROTECTI & INSPECT CARRI
3. HOIST CARRIER F TRANSPORT BASE

EQUIPMENT:

BRIDGE CRANE
SLING SET
HYDRA-SET (5-TO
ACCESS PLATFORM
WORK STAND, MOB
TRANSPORT BASE
SEMI-TRAILER
BREATHER

MSOB

AST ALTITUDE CHAMBER

CARRIER SUSPENDED ABOVE CSM IN ALTITUDE CHAMBER

OCKING TEST

TEPS:

. POSITION CARRIER OVER CSM IN ALTITUDE CHAMBER
. MECHANICALLY MATE CARRIER TO CM DOCKING RING
. CARRIER/CSM LEAK TEST

UIPMENT:

BRIDGE CRANE
SLING SET
HYDRA-SET (5-TON)
VACUUM CHAMBER ACCESS PLATFORMS
TOOLS
TAG LINES

EAC

CARRIER SUSPENDED ABOVE CSM, OR SIDE BY SIDE

COMBINED CSTS & MISSION SIMULATION

CARRIER/CSM INTERFACE TESTS
D&C AND DMS TESTS
MISSION SIMULATION

OVERHEAD CRANE

MOVEMENT OF CARRIER TO WEST ALTITUDE CHAMBER

STEPS:

1. UNDOCK & DISCONNECT CARRIER
2. ROTATE CARRIER TO VERTICAL ATTITUDE

EQUIPMENT:

ROTATION FIXTURE
SLING SET
HYDRA-SET
TAG LINES

WEST ALTI

CARRIER SUPPORT

PRESSURE A

STEPS:

1. INSTALL SUPPORT

EQUIPMENT:

BRIDGE
SLING SE
HYDRA-SE
TAG LINE
VACUUM
TOOLS
ATTACHME

AST ALTITUDE CHAMBER

CARRIER SUSPENDED ABOVE CSM IN OPEN ALTITUDE CHAMBER

OCKING TEST

EPS & EQUIPMENT:

SAME AS ABOVE

OVERHEAD CRANE

MOVEMENT OF CARRIER TO WEST ALTITUDE CHAMBER

STEPS & EQUIPMENT:

SAME AS ABOVE

WEST ALTITUDE CHAMBER

CARRIER ON SUPPORT BASE

PRESSURE AND LEAK TESTS
CARRIER/CSM INTERFACE TEST
D&C AND DMS TESTS
MISSION SIMULATION
QUALITY SURVEILLANCE

STEPS & EQUIPMENT:

SAME AS ABOVE

1A CARRIER GROUND HANDLING AND TRANSPORTATION - KSC

MSOB

OVERHEAD CRANE

MOVEMENT OF
CARRIER TO
ASSEMBLY &
TEST AREA

A&T AREA

CARRIER ON
SUPPORT BASE

ASSEMBLY

STEPS:

1. INSTALL CARRIER ON SUPPORT BASE & REMOVE BREATHER
2. INSTALL COMPONENTS

EQUIPMENT:

BRIDGE CRANE
SLING SET
HYDRA-SET (5-TON)
ACCESS PLATFORM SET
HOISTING TRAY
PLATFORM TRUCK
TAG LINES
TOOLS
SUPPORT BASE
ATTACHMENT KIT

OVERHEAD CRANE

MOVEMENT OF
CARRIER TO EAST
INTEGRATION STAND

TION

RAILER
A&T AREA
VE COVER
ER
ROM

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NLE

FIT

STEP

1. I
L
2. I
C
3. R
4. H
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CARR

BR
SE
HY
SE
A
TA

TUDE CHAMBER

ON CHAMBER
BASE

ND LEAK TESTS

CARRIER ON CHAMBER
BASE

RANE
T
T
S
HAMBER ACCESS PLATFORMS

NT KIT

AND

OVERHEAD CRANE

MOVEMENT OF
CARRIER TO
A&T AREA

STEPS:

1. ATTACH HANDLING SLING AND HOIST CARRIER
2. INSTALL CARRIER ON SUPPORT BASE IN AISLE
3. CHANGE TO LOW BAY CRANE

EQUIPMENT:

SUPPORT BASE
SLING SET
HYDRA-SET (5-TON)
TOOLS
ATTACHMENT KIT
TAG LINES

A&T AREA

CARRIER ON
SUPPORT
BASE

EXPERIMENT ALIGNMENT VERIFICATION

STEPS:

1. INSTALL CARRIER ON SUPPORT BASE
2. ALIGN EXPERIMENTS AS NECESSARY

EQUIPMENT:

SUPPORT BASE
EXPERIMENT OPTICAL ALIGNMENT SET
ACCESS PLATFORM SET
TOOLS
BRIDGE CRANE
HYDRA-SET (5-TON)
SLING SET
TIE LINES
ATTACHMENT KIT

MSOB

AST INTEGRATION STAND

CARRIER ATTACHED
TO LOWER SLA

OVERHEAD CRANE

MOVEMENT OF
CARRIER TO A&T
AREA

A&T AREA

CARRIER ON
SUPPORT BASE

OVERHEAD CRANE

MOVEMENT OF
CARRIER TO
CLEANING
POSITIONER

CHECK

S:

NSTALL CARRIER ON
OWER SLA
NSTALL UPPER SLA &
OMPLETE FIT CHECK
EMOVE UPPER SLA
OIST CARRIER FOR
OVEMENT TO A&T AREA

IER EQUIPMENT:

RIDGE CRANE
LING SET
YDRA-SET (5-TON)
LA INTERNAL ACCESS PLATFORM SET
TTACHMENT KIT
AG LINES

ASSEMBLY & TEST

STEPS:

1. INSTALL CARRIER ON SUPPORT BASE
2. INSTALL EXPERIMENTS
3. ALIGN EXPERIMENTS
4. PERFORM S/S & SYS ELECT TESTS

EQUIPMENT:

BRIDGE CRANE
SLING SET
HOISTING TRAY
PLATFORM TRUCK
ACCESS PLATFORM SET
HYDRA-SET (5-TON)
EXPERIMENT GRIPS &
SLING SET
DOME HANDLING SET
TRANSIT/COLLIMATOR
ALIGNMENT KIT
TOOLS
ATTACHMENT KIT

MSOB

VERHEAD CRANE

MOVEMENT OF
CARRIER TO
EAST INTEGRATION
STAND

EAST INTEGRATION STAND

CARRIER INSTALLED
IN SLA

OVER THE ROAD

MOVEMENT OF
SPACECRAFT ON
TRANSPORT
TRAILER TO LC34

LC

MATE CARRIER & SLA

STEPS:

1. INSTALL CARRIER ON LOWER SLA
2. INSTALL UPPER SLA
3. NORMAL APOLLO S/C BUILDUP

EQUIPMENT:

BRIDGE CRANE
SLING SET
HYDRA-SET(5-TON)
SLA INTERNAL ACCESS PLATFORM SET
DOME HANDLING SET
AUXILIARY WORK STAND SET
ATTACHMENT KIT
TAG LINES

NORMAL APOLLO TRANSPORTATION

IN

ST

1.
2.

EC

FOLDOUT FRAME 3

LOW BAY AREA

CARRIER IN CLEANING POSITIONER

CLEANING

INSTALL CARRIER IN CLEANING POSITIONER

EQUIPMENT:

BRIDGE CRANE
SLING SET
HYDRA-SET (5-TON)
ACCESS PLATFORM
ATTACHMENT KIT
VACUUM CLEANING EQUIPMENT
TAG LINES
TOOLS
CLEANING POSITIONER ADAPTER

MSOB OR PIB

MOVEMENT OF CARRIER TO WEIGHT & BALANCE AREA

MSOB:

EQUIPMENT: BRIDGE CRANE, ETC.

ALTERNATE: PIB

TRANSPORT CARRIER TO PIB FOR WEIGHT & BALANCE DETERMINATION

EQUIPMENT:

BRIDGE CRANE
SLING SET
HYDRA-SET (5-TON)
ACCESS PLATFORM
TRANSPORT BASE
PROTECTIVE COVER
SEMI-TRAILER & TRACTOR TRUCK

MSOB OR PIB

CARRIER ON WEIGHT & BALANCE FRAME

WEIGHT & BALANCE

MSOB:

STEPS:

1. INSTALL CARRIER IN VERTICAL ATTITUDE ON MASS PROPERTIES FIXTURE
2. INSTALL EXPERIMENT MASS SIMULATORS
3. ROTATE CARRIER AND INSTALL ON MASS PROPERTIES FIXTURE IN HORIZONTAL ATTITUDE
4. REMOVE CARRIER FROM FIXTURE AND ROTATE TO INVERTED ATTITUDE FOR MOVEMENT IN MSOB.

ALTERNATE: PIB

STEPS:

1. SAME AS 1 & 2 ABOVE
2. REMOVE CARRIER FROM FIXTURE & ROTATE TO VERTICAL ATTITUDE
3. INSTALL CARRIER ON TRANSPORT BASE & SEMI-TRAILER
4. INSTALL PROTECTIVE COVER

EQUIPMENT:

BRIDGE CRANE
SLING SET
HYDRA-SET (5-TON)
WORK STANDS
MASS PROPERTIES FIXTURE SET
ROTATION FIXTURE
EXPERIMENT MASS SIMULATOR SET
SIMULATOR HANDLING & INSTALLAT

34

SAT I/SPACECRAFT ON PAD WITH MOBILE SERVICE STRUCTURE IN PLACE

STALL, TEST & SERVICE

EPS:

INSTALL LATE EXPERIMENTS
INSTALL BATTERIES

UIPMENT:

SLA INTERNAL ACCESS PLATFORM SET
BATTERY INSTALLATION KIT
EXPERIMENT GRIPS & SLING SET
DOME HANDLING SET
PLATFORM TRUCK
AUXILIARY WORK STAND SET
TOOLS
COMPONENTS HANDLING KIT

OVERHEAD CRANE OR BY ROAD

MOVEMENT OF CARRIER TO EAST ALTITUDE CHAMBER AREA

MSOB:

STEPS:

1. INSTALL CARRIER ON SUPPORT BASE
2. CHANGE TO HIGH BAY CRANE

ALTERNATE: PIB TO MSOB

STEPS:

1. TRANSPORT CARRIER TO MSOB
2. POSITION TRAILER IN UNLOADING AREA
3. REMOVE COVER AND ATTACH HANDLING SLING
4. RAISE CARRIER AND INSTALL ON ROTATION FIXTURE
5. ROTATE CARRIER TO INVERTED POSITION
6. ATTACH HANDLING SLING & MOVE CARRIER TO SUPPORT BASE ADJACENT TO ALTITUDE CHAMBER
7. CHANGE TO HIGH BAY CRANE

EQUIPMENT:

SUPPORT BASE
HANDLING SLINGS
BRIDGE CRANE
HYDRA-SET
ATTACHMENT KIT

ION SET

FIGURE 2 HANDLING AND TRANSPORTATION FLOW DIAGRAM - KSC

FOLDOUT FRAME 5

3.3 Baseline

Table I presents a composite list of the handling,access and transportation items required to support the integrated 1A carrier system during Denver and KSC ground operations. The majority of these items did not require trade analysis as shown by review of the functional matrix in Table A-I, Appendix A. In these cases, end items were selected directly without detailed analysis. Those areas which involved high cost equipment or special considerations were analyzed and traded-off in more detail. Results of these analysis are presented below:

3.3.1 SLA Internal Access

Access is required to the carrier when it is installed within the SLA during fit check and spacecraft buildup operations within the MSO building and during checkout, test and servicing activities at the launch pad. Specific internal SLA stations requiring access are: (1) carrier dome area, (2) the carrier side truss and rack areas, and (3) docking ring and tunnel area. Two general approaches were considered: (1) provisioning of a new platform set, and (2) modifying the NAA provided LM set.

New provisioning requires a high initial procurement cost of approximately $250,000. On the other hand, $50,000 represents the approximate cost of modifying an existing set of LM platforms.

Provisioning of the modified NAA furnished LM set was selected on the basis of cost and development schedule.

3.3.1.1 Access to Carrier Dome Area

Access is required to station Xa 562 to facilitate carrier dome removal and installation operations, provide access to the carrier interior with the lower dome removed and provide access to experiments mounted on the experiment rack.

A criss-cross platform will be added at Level Xa 525 as shown in Figure 3. Two platform systems at right angles to each other span the distance between the SLA walls. The center segments are removable so that the dome can be lowered. The platform segments are supported by tie rods attached to SLA hard

TABLE I HANDLING AND TRANSPOR[T...]

EQUIPMENT ITEM	QUANTITY REQUIRED	EXISTING EQUIP NO MOD	EXIS[TING] EQU[IP] ...
A. HANDLING			
SLING SET	1		
HYDRA-SET, 5-TON CAP	1	x	
SUPPORT BASE - ASSEMBLY & TEST	2		
SUPPORT BASE - ALTITUDE CHAMBER	1		
ROTATION FIXTURE	1		
CARRIER ATTACHMENT KIT	1		
MASS PROPERTIES TEST FIXTURE SET	1		
EXPERIMENT GRIPS AND SLING SET	1		
EXPERIMENT MASS SIMULATOR SET	1		
BATTERY INSTALLATION KIT	1		
TRANSIT/COLLIMATOR ALIGNMENT KIT	1		
CLEANING POSITIONER	1		
ACCESS PLATFORM SET	1		
B-1 MOBILE ACCESS PLATFORM	1	x	
B-2 MOBILE ACCESS PLATFORM	1	x	
MOBILE WORK STAND	1	x	
ALTITUDE CHAMBER PORTABLE PLATFORM SET	1		
AUXILIARY WORK STAND SET	1		
CARRIER INTERNAL PLATFORM AND LADDER SET	1		
SLA INTERNAL ACCESS PLATFORM SET	1		
HOISTING TRAY	1		
DOME HANDLING SET	1		
PLATFORM TRUCK	1		
TRAINER HANDLING SET	1		
B. TRANSPORTATION AND STORAGE			
SEMI-TRAILER	2	x	
MOBILE CRANE	2	x	
LOADING TRAILER, CLT-45	2	x	
TRANSPORT BASE	2		
B377PG TRANSPORTATION KIT	1		
PROTECTIVE COVER	2		
BREATHER KIT	1		

Fold out Frame I

ATION MATRIX OF MAJOR EQUIPMENT

STING IP PLUS MOD	EXISTING DESIGN NEW BUILD	NEW DESIGN NEW BUILD	PROBABLE SOURCE
		x	CFE
			MSOB FACILITY ITEM
		x	CFE
		x	CFE
		x	CFE
		x	CFE
		x	CFE TEST TOOL
		x	CFE
		x	CFE TEST TOOL
		x	CFE
		x	CFE
x			APOLLO (MOD TO NAA MODEL A14-014)
		x	CFE
			GFE (FSN 1730-390-5618)
			GFE (FSN 1730-390-5620)
			CFE
		x	CFE
		x	CFE
		x	CFE
x			APOLLO (MOD TO NAA MODEL H14-176-101)
	x		CFE
		x	CFE
	x		CFE
		x	CFE
			MMC MOTOR POOL - KSC MOTOR POOL
			MMC RENTAL - KSC MOTOR POOL
			GFE NASA - KSC APOLLO
		x	CFE
x			NASA
		x	CFE
		x	CFE

Fold out FRAME II

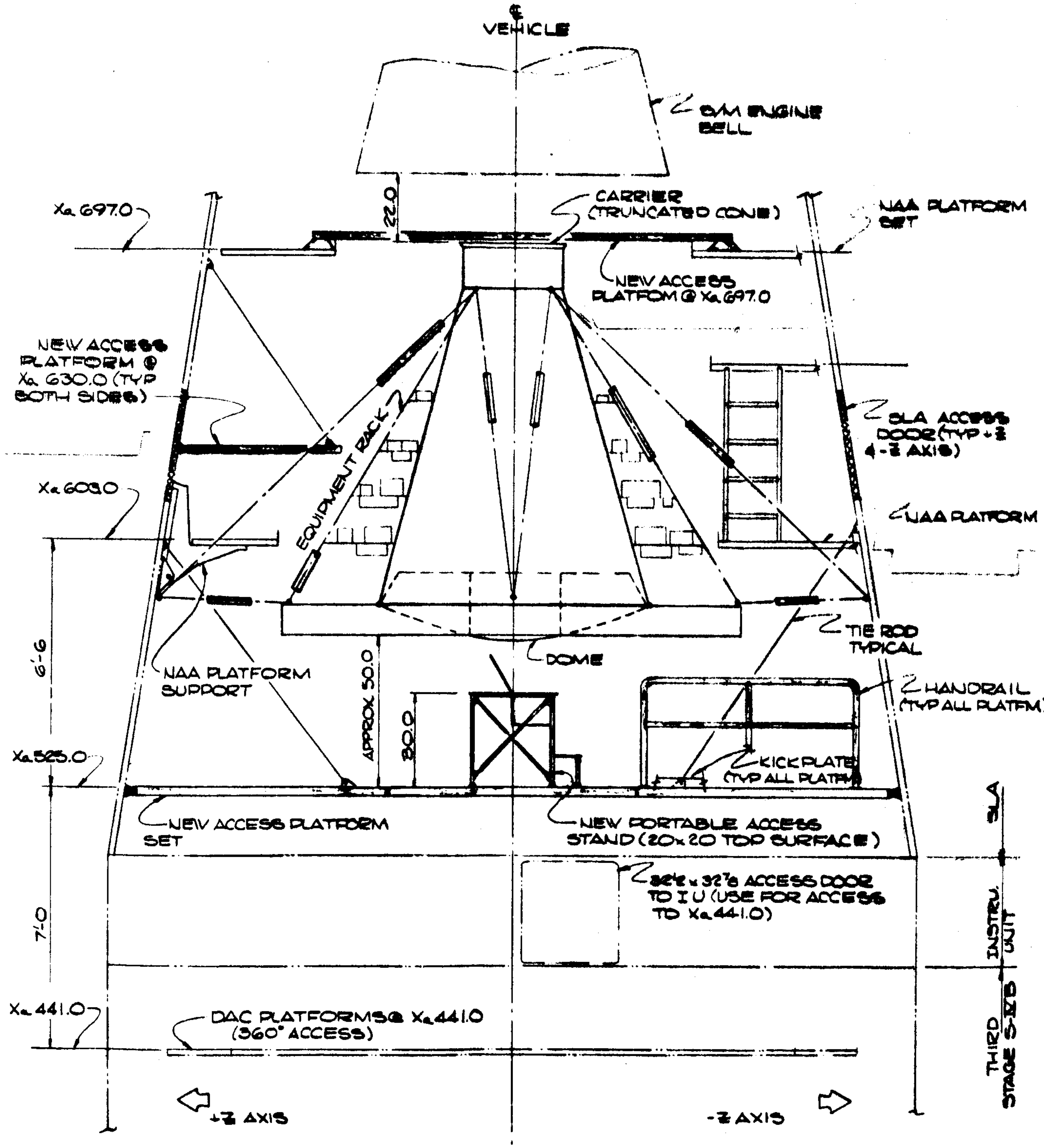


Figure 5 SLA Internal Access Platforms - Elevation

3.3.1.1 (continued)

points at approximately Level Xa 603. The center panels of this platform can be repositioned temporarily to allow the dome to be pivoted into a slung down position as shown in Figure 4.

3.3.1.2 Dome Removal - Various approaches were considered to meet the requirement of providing dome handling within the SLA. Of those considered, the use of a GSE Hinge Set or a Handling Cart appeared most feasible. The dome assembly, weighing approximately 120 lbs. has pressure seal camera windows and one of the experiment airlocks. Its outer surface is insulated with multi-layer aluminum coated Mylar. The dome requires special handling. The first concept provides a means for hinging the dome at the base of the carrier by employing removable ground support hinges (see Figure 5). The alternate concept provides for a cart to operate over track on new SLA access platforms at Level Xa 525. A four cable hoist system suspended from the carrier trusses mechanically raises the cart until it comes in contact with the dome which is bolted to the base of the carrier. The bolts are removed and the dome is lowered on the cart to the platform below. The track allows the cart and dome to be moved out of the way (see Figure 6). It was decided that there was less probability of damage to the dome due to handling when employing the GSE Hinge Set concept than when using the Handling Cart concept. Access to the removed dome area is provided by an auxiliary work stand shown in Figure 3.

Access to the external experiment rack from bottom side is provided directly from the criss-cross platform.

3.3.1.3 Access to Carrier Side Subsystem Racks

Access must be provided to the carrier side areas to facilitate battery installation and access to communications equipment. This requirement is met by provisioning new platforms at Level Xa 630, as shown in Figures 3 and 7 and using the existing LM platforms at Level Xa 603 (Figure 8).

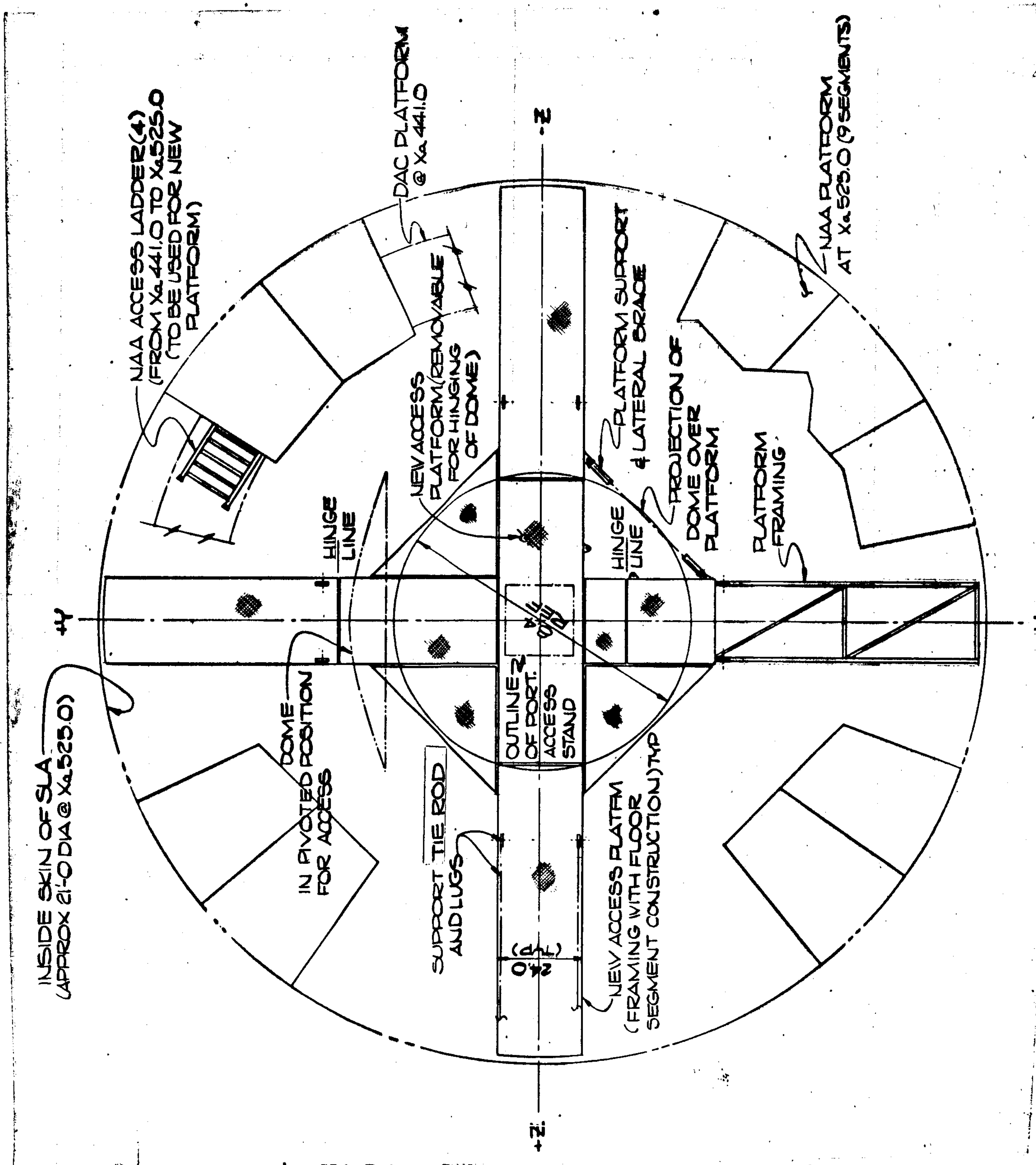


Figure 4 SLA Internal Access - Plan View, Level X_A 525

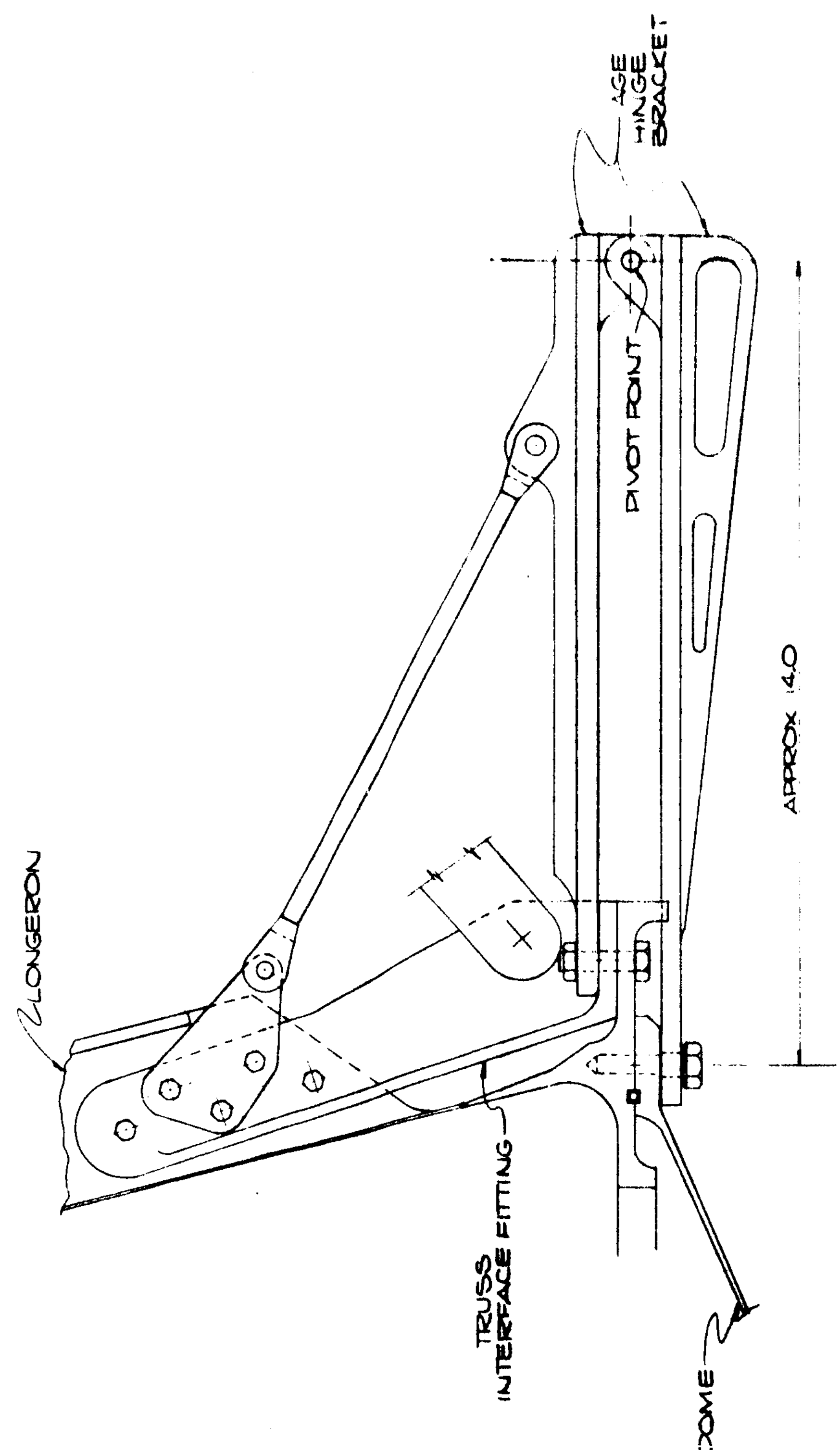


Figure 5 Carrier Dome GSE Hinge Concept

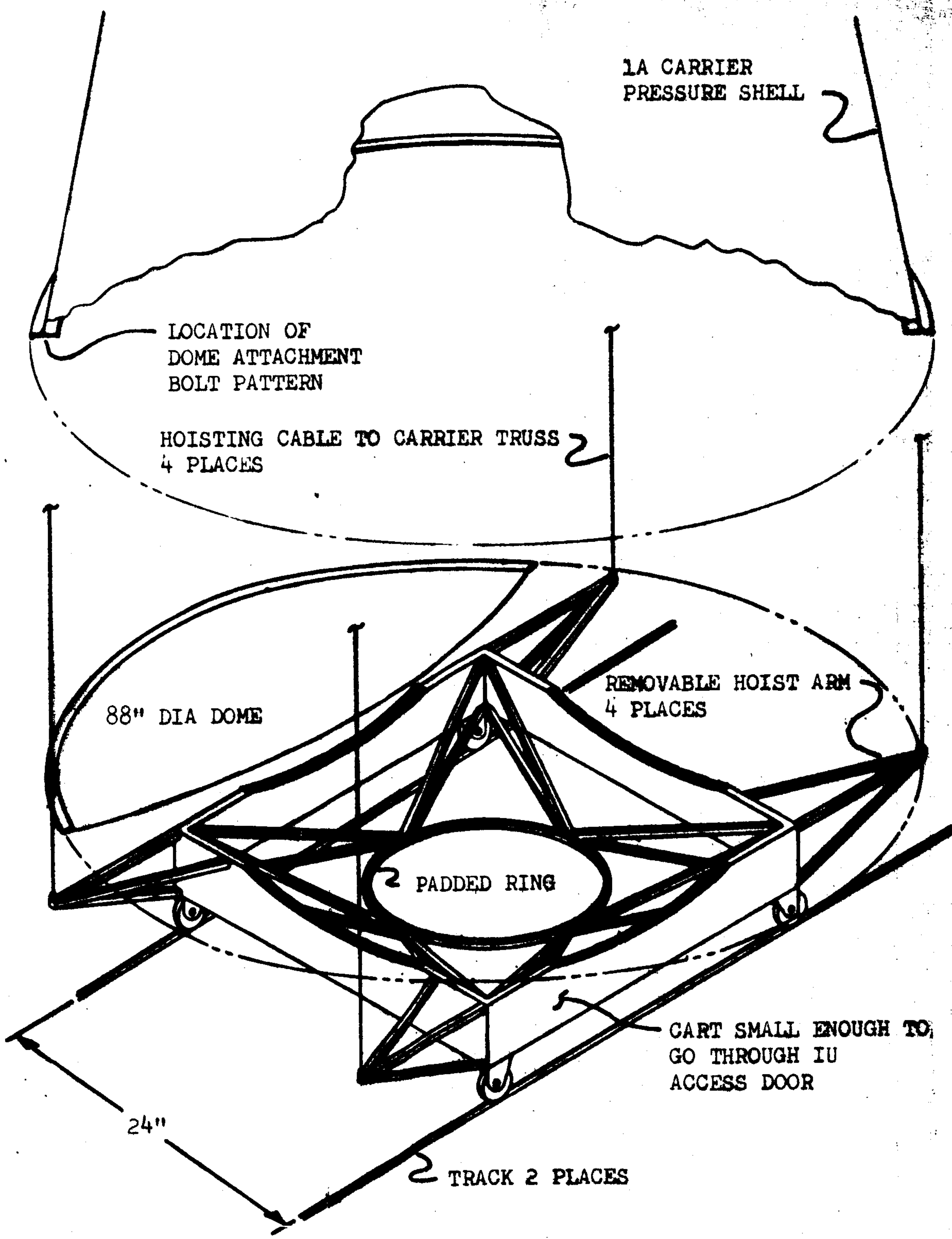


Figure 6 Alternate Dome Removal Concept

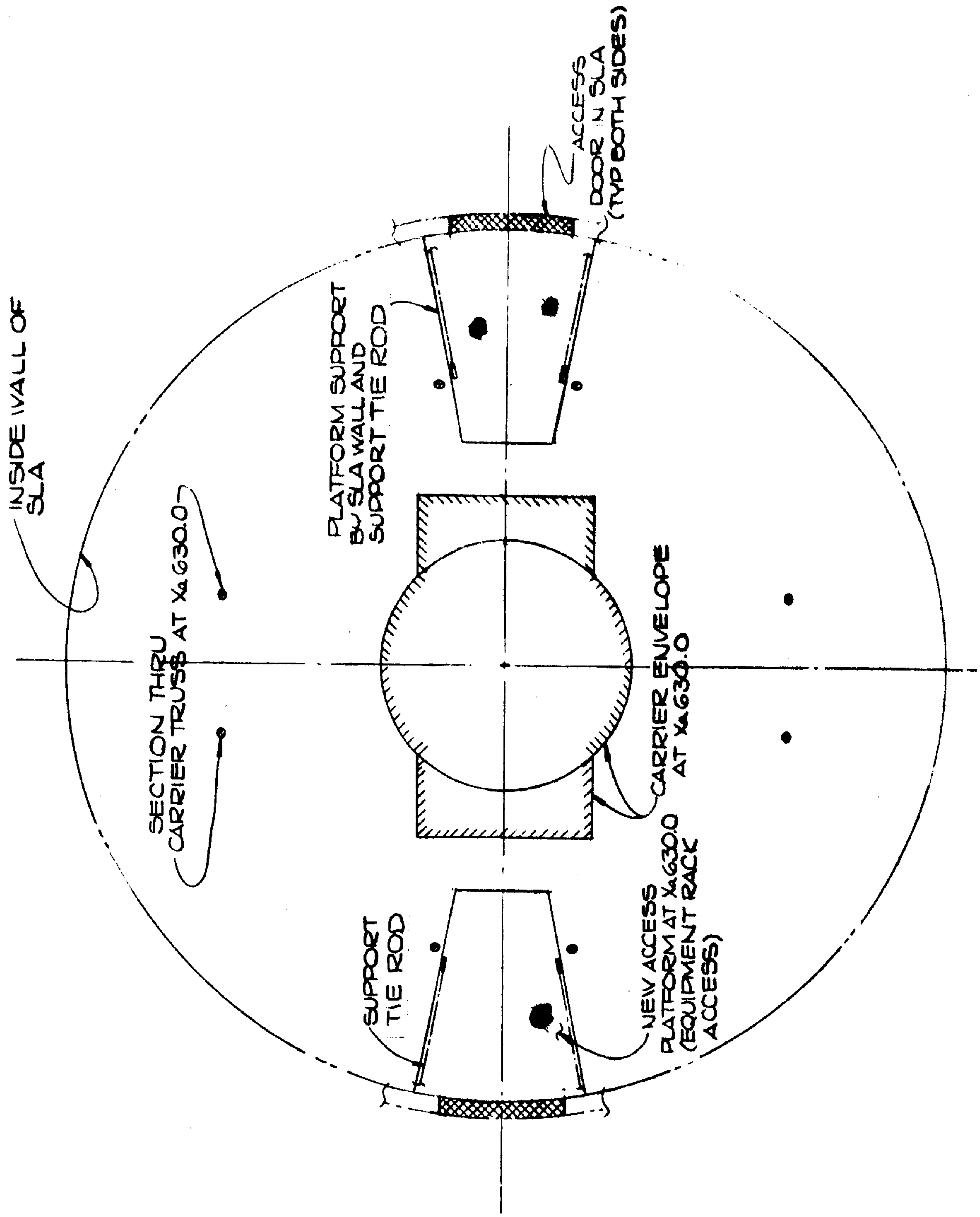


Figure 7 SLA Internal Access - Plan View, Level X_A 630

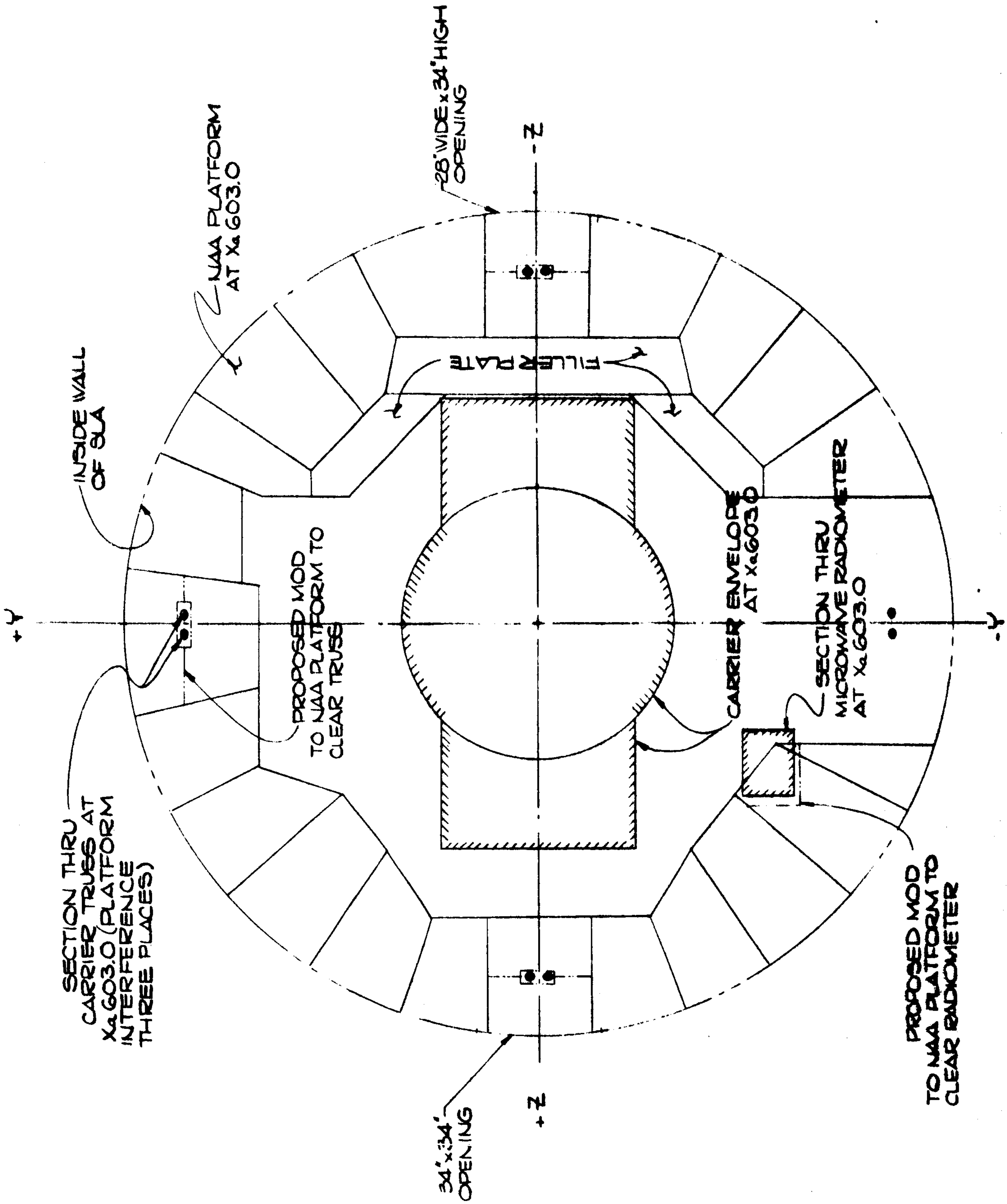


Figure 8 SLA Access - Plan View, Level X_A 603

3.3.1.4 Access to Docking Ring and Tunnel

Carrier tunnel interior access is provided by adding a scaffold at Level Xa 697 (Figures 3 and 9) and provisioning a ladder to be slung from the docking ring down into the tunnel interior.

3.3.1.5 Additional Access Capabilities

The existing LM work platforms provide access to spacecraft stations Xa 525, 603, 697, and 759. The platform set has provisions (ladders and trap doors) for climbing from certain levels to the next without having to leave the SLA. The installation, utilization or removal of Xa 525 platform segments requires access from the Instrument Unit (IU). IBM provided the internal work platforms at Level Xa 477 in the IU and Douglas provided the platform set in the S-IVB forward interstage at Level Xa 441.

The Xa 477, 441, and 525 platform segments must be brought in and taken out in a fixed sequence through the opening in the IU. Four ladders, resting on the Xa 441 platforms, provide the only access to Xa 525 platforms. The Xa 603 to Xa 759 platform segments must be brought in and taken out in sequence through two opposed openings in the SLA.

Douglas also provided a components handling cart to move along the inner edge of the Xa 441 platform, and also a monorail hoist for lifting components through the IU opening.

As Figure 8 shows, an interference occurs between the carrier truss structure and three of the existing platform segments. Also, one section of platform must be trimmed in order to provide clearance for the S044A Microwave Radiometer. These platform sections will be modified to alleviate this interference.

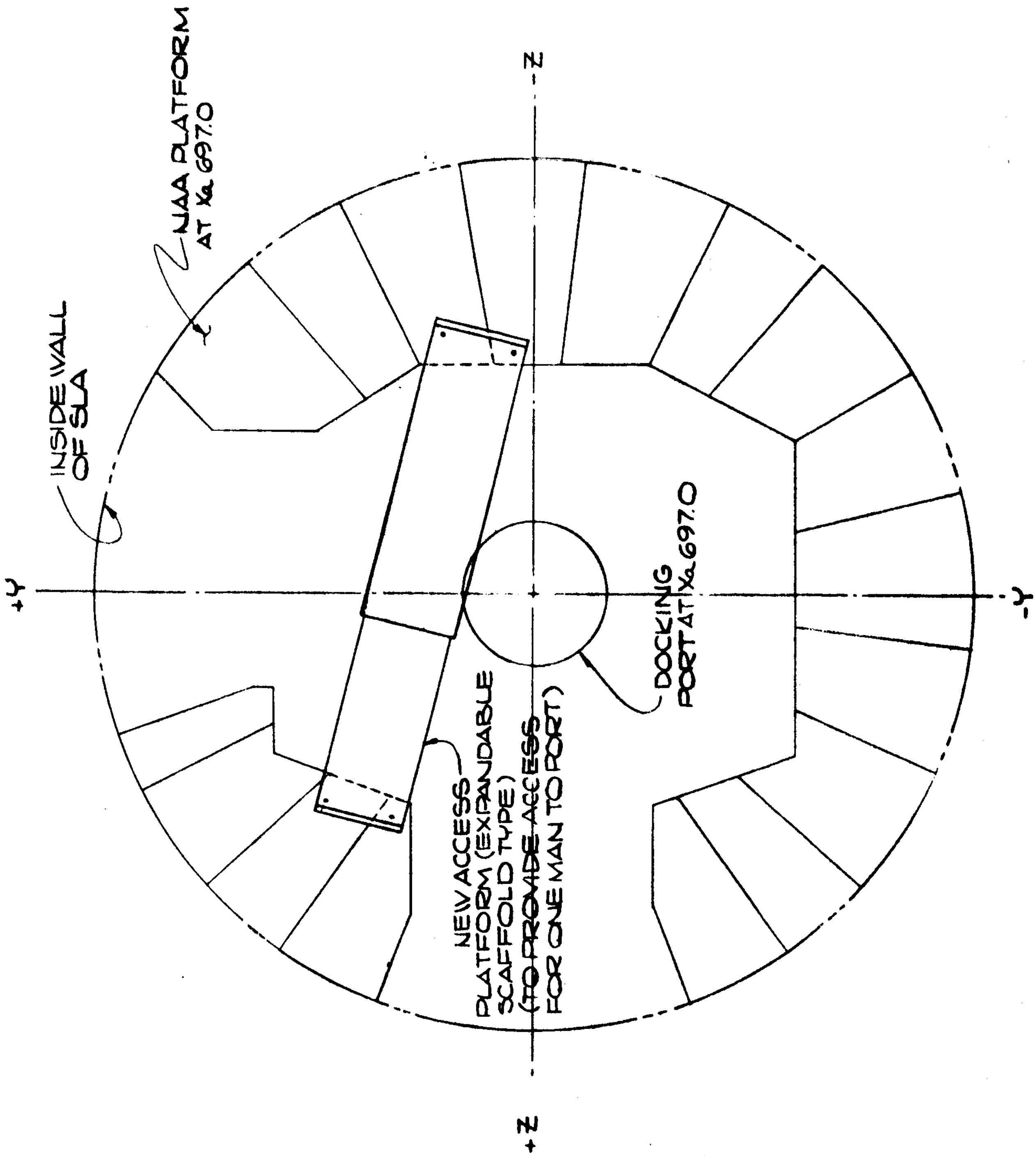


Figure 9 SLA Access - Plan View, Level X_A 697

3.3.2 Carrier Handling Equipment

For the most part at Denver, one common set of handling, access and transportation equipment suffices to support assembly and test operations. However, the test schedule at Denver requires a quantity of two of the following: carrier transport base, support base, and protective cover. Most of the carrier assembly and test occurs in the manufacturing fixture. The GSE equivalent of this fixture (the Assembly and Installation Fixture) is used at the SSL and in the pack and ship area after which the support base is dismantled and shipped to KSC. The carrier is installed on this support base by means of four pickup locations at the truss hardpoints. An external access platform set, internal platform and ladder set, hoisting tray, platform truck, etc., support operations when the carrier is on the support base. Movement of the carrier from one section to the next within a facility is by bridge crane. The carrier is generally handled in the vertical attitude using a sling set and a 5-ton capacity Hydra-Set. The sling pickup points are the four truss SLA attach hardpoints.

Other handling attitudes which must be met are (1) 90° rotation to horizontal for weight and balance activities, and (2) 180° rotation to allow docking test with the CSM within the MSOB altitude chamber. Both operations are accomplished by use of a trunnion set in conjunction with the handling sling set.

3.3.3 Experiments and Components Handling Equipment

A set of grips, slings and lifting devices is required to install, remove and handle heavy experiments. Experiments are equally divided between CFE and GFE. Reusable shipping containers, assembly stands and special tools are furnished by the individual experiment contractors. MMC will provide that handling and installation equipment which is peculiar to the IA carrier. Most experiments and components can be hand carried and installed. Those items too heavy for hand installation are governed by the criteria in Table II.

3.3.3 (continued)

TABLE II - CRITERIA FOR HANDLING EXPERIMENTS AND COMPONENTS WITHIN THE SLA

1. Components weighing more than 60 lbs. require mechanical or power hoists.

2. Components weighing more than 45 lbs. and lifted more than 5 feet require mechanical or power hoist.

3. Components weighing more than 45 lbs. and less than 60 lbs. require provisions for a two man lift if:

   Component is difficult to handle

   Work space is restricted

   Precise positioning or delicate handling is required

   Task is repeated frequently

   Required force is applied continuously for more than one minute.

4. Components designed to be removed and replaced require handles or other suitable means for grasping, handling and carrying.

5. A non-slip grasp surface (e.g., grooved or frictional) is necessary where a component installation requires that its bottom surface be used to hold it during installation or removal.

6. Loose items, weighing five pounds or more, require tethering or suitable restraint to prevent damage to the carrier or S-IVB tank dome.

Table III identifies experiments and components requiring assist for installation or removal from the carrier after the carrier has been installed in the SLA.

Also, requirements will be met by providing an experiment grips and sling set. Details of this set will be developed as experiment design progresses.

Table III Handling Methods for Heavy Experiments and Components Within the SLA

LOCATION	COMPONENT IDENTITY	HANDLING METHOD	UNIT WEIGHT (LB)
Carrier Interior	E06-1 Metric Camera		200
	T004 Frog Otolith Function	Mech. Hoist	85.9
	S019 UV Stellar Astronomy Camera		43
	S020 UV X-Ray Solar Photography		35.2
Carrier Exterior	Batteries - 7 Places	Mech. Hoist	140 Ea.
	S017 X-Ray Sensor	Mech. Hoist	176
	Data System	Mech. Hoist	70
	Electronics	2-Man Lift	46
	S040 Dielectric Tape Camera	Mech. Hoist	64
	E06-9 Infra Red Radiometer/ Spectrometer	2 Man Lift	50
	E06-11 Multifreq Microwave Radiometer	2 Man Lift	50

3.3.4 Over-the-Road Transportation

Various approaches were considered to meet the requirement of providing over-the-road transportation of the integrated carrier. The underlying factor controlling the design of the roadable conveyance for the IA carrier stems from the manner in which cargo is secured in the Pregnant Guppy aircraft. That is, a pallet which is a part of the aircraft is moved out into a loading trailer. Cargo, mounted on a transport base, is hoisted by mobile crane onto the pallet. Tiedown is made between the base and the aircraft pallet. Then the pallet is moved into the cargo compartment and pin connected to the two floor tracks.

The Titan Stage II trailer, the SLA transport dolly, etc., were rejected as candidates early in the study because of not being compatible with the Pregnant Guppy loading operation (they are too wide and will not fit the aircraft cargo pallet).

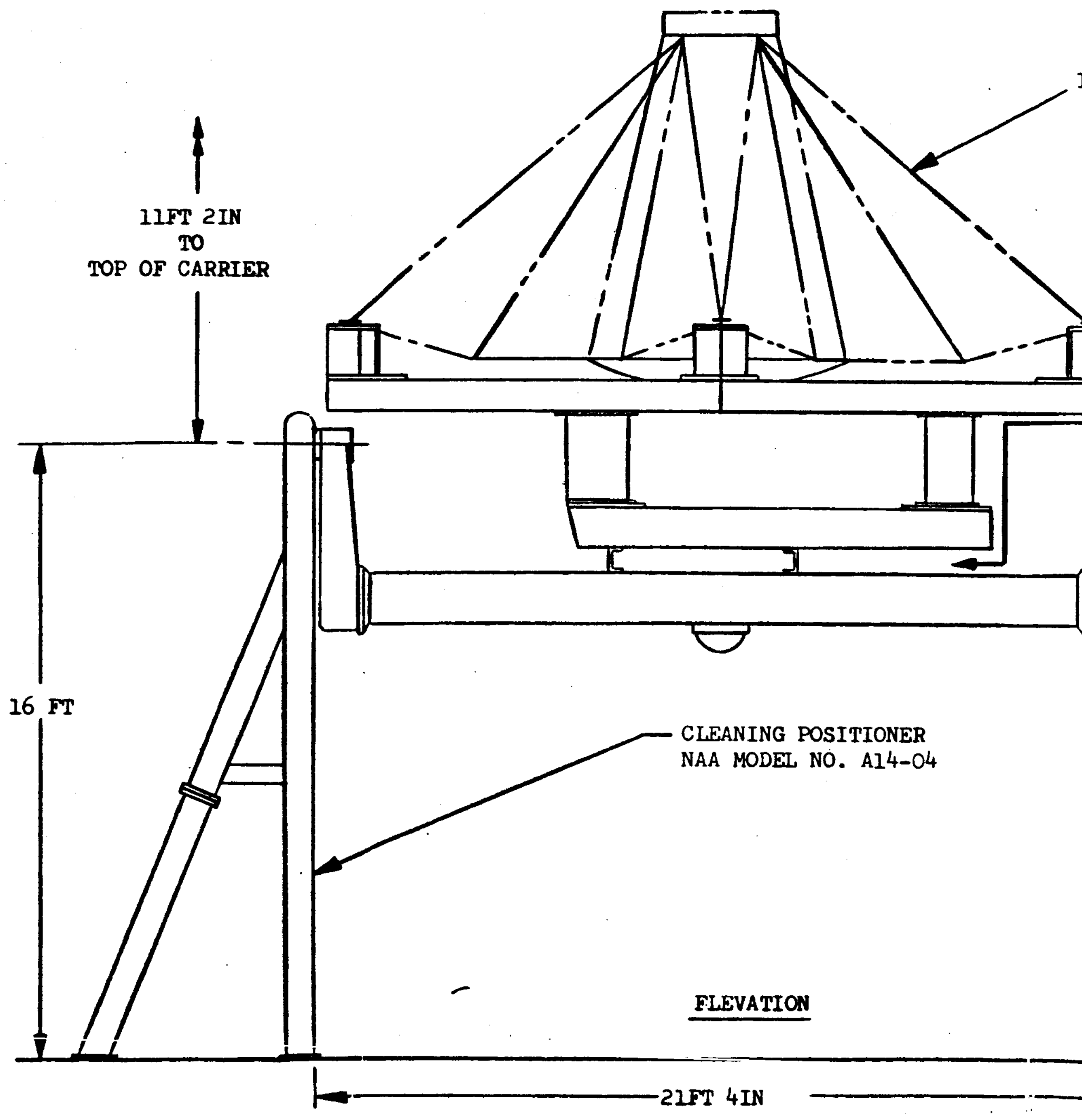
Commercial trailers are considered the best choice since only one integrated carrier is to be transported. The vehicle can be any drop frame semi-trailer equipped with air-ride suspension. The carrier transport base is 9 feet wide which is compatible with most commercial trailer widths. A trailer can be provided from the MMC Denver motor pool and from the NASA motor pool at KSC.

3.3.5 Carrier Final Cleaning

Several approaches were considered to meet the requirements of providing positioning of the IA Carrier for final cleaning at KSC. There is an Apollo Cleaning Fixture existing at KSC. The approaches were narrowed down to modifying this fixture or providing a completely new fixture.

New provisioning of the NAA design cleaning positioner requires a high initial procurement cost of approximately $235,000. The adapter to fit the LM to the cleaning positioner costs approximately $4500.

It was decided to provide a low cost IA Carrier adapter for joint usage of the cleaning adapter which is located in the MSO Building. The proposed design is depicted in Figure 10.



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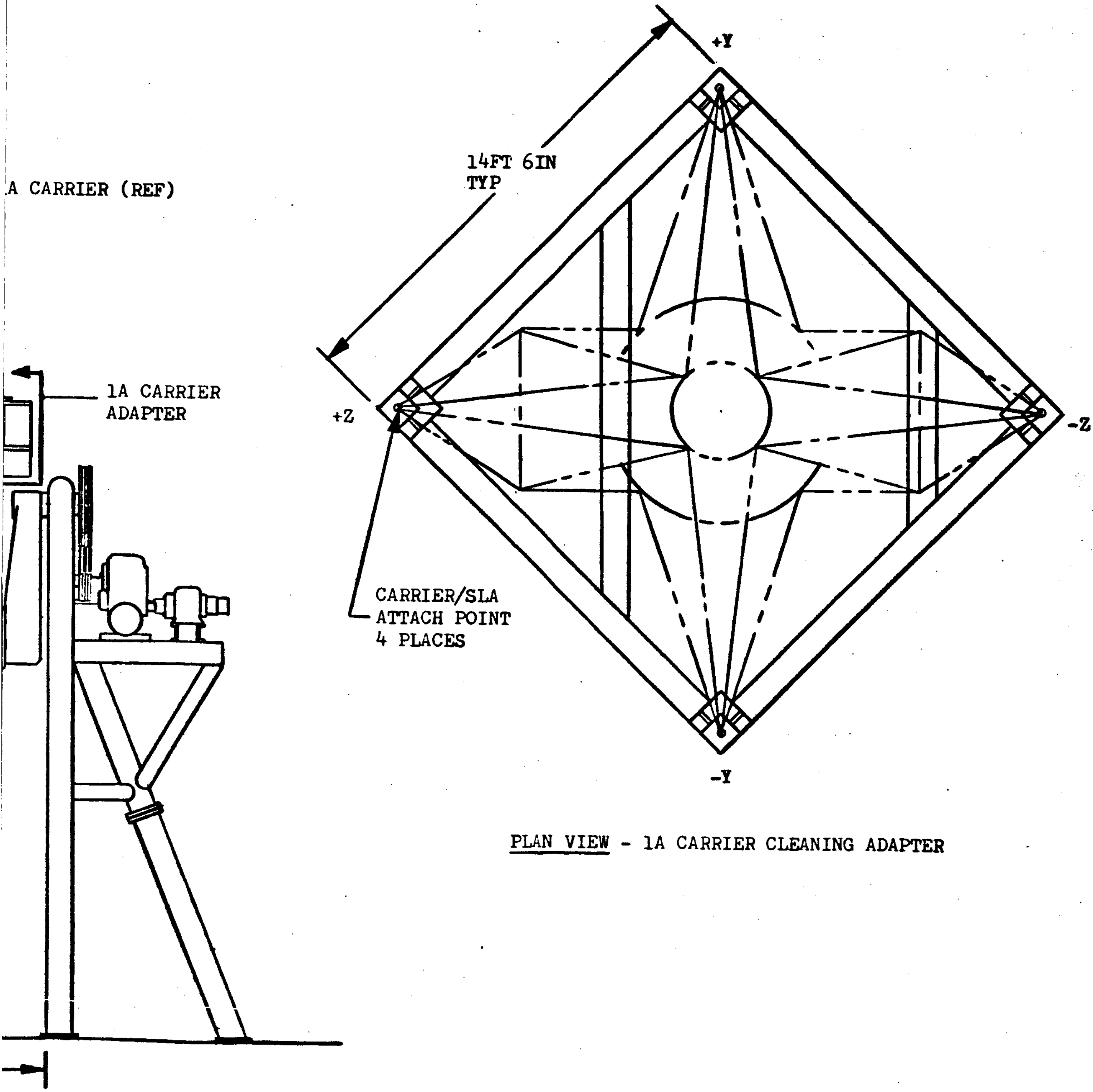

PLAN VIEW - 1A CARRIER CLEANING ADAPTER

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FIGURE 10-CLEANING POSITIONER AT KSC

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3.3.6 Experiment Alignment to Carrier

Alignment requirements have been identified for nine of the IA experiments. These requirements are listed in Table IV.

Some of these experiments will be installed on the Carrier in the SATF at Denver; those which may not be available at the time will be installed on the carrier at KSC in the MSO Building. Initial alignment of those experiments that are installed at Denver will be by means of manufacturing tooling. All alignment operations at KSC will utilize a GSE alignment set.

This set will include major items such as an autocollimator unit and two precision jig transits mounted on individual support stands. Targets will be provided on an extension of the autocollimator unit to permit verification of line-of-sight in two planes.

Initial alignment will be performed for all experiments installed at KSC. Final alignment identification will be performed for all experiments to ensure the requirements as set forth in Table III are met. Optical alignment of the experiments with the carrier will be accomplished by utilizing a reflective surface or mirror which is to be provided as part of each involved experiment. Initially, the carrier line-of-sight axis will be established by use of the autocollimator, transit and targets mounted on the carrier. Each experiment in turn will be aligned with the established carrier line-of-sight axis by utilizing the experiment reflective surface, the autocollimator and jig transits. The autocollimator line-of-sight axis will be established in the same reference attitude as the carrier reference axis by the jig transits and a series of optical targets on the autocollimator unit extension. The experiment will be adjusted until the reflective surface has been brought perpendicular to the autocollimator line-of-sight and thereby aligned with the carrier.

For experiments not available for initial installation at SATF, a simulator will be provided so that a proper alignment procedure can be verified. Optical alignment operations are not feasible after spacecraft build-up. Under these circumstances, alignment will depend on correct mounting as determined by prior mounting/alignment operations.

Table IV - Tolerance for Experiment Alignment to Carrier

Exp. No.	Experiment Name	Alignment Tolerance
S039	Day/Night Camera Camera located carrier exterior	± 3°
S040	Dielectric Tape Camera Camera located carrier exterior	± 10°
S043 (S075)	IR Temperature Sounding Radiometer located carrier exterior	± .5°
S044A	Electric Scanned MW Radiometer Radiometer located carrier exterior	± .5°
S048	UHF Sferics Antenna located carrier exterior	± .5°
E06-1	Metric Camera Camera located carrier interior	± .5°
E06-4	Multispectral Camera Cameras (6) located carrier interior	± 10 arc min.
E06-7	IR Imager Scanner located carrier exterior	± .5°
E06-11	Multifrequency Microwave Radiometer Antenna/electronics located carrier exterior	± .5°

4. CONCLUSIONS AND RECOMMENDATIONS

In general, there are no 1A carrier handling, access or transportation requirements which cannot be met by an approach completely compatible with normal Apollo operations.

Some of the existing Apollo line GSE can be utilized to meet 1A requirements such as the SLA internal access platform set, mobile access platforms, the LM cleaning positioner, Guppy transportation and loading kit, and Hydra-Set assembly.

SLA internal access to the 1A carrier can be provided by using a basic LM, NAA furnished, platform set with modifications and additions as defined in this report. New provisioning of a set, basic to the 1A carrier requires a high initial procurement cost of approximately $250,000. It is recommended that joint usage of one of the existing LM sets be implemented since it would entail only a $50,000 modification cost. Analysis is required of Apollo timeline schedules in order to ascertain that joint usage is feasible.

It is recommended that the existing KSC cleaning positioner already in joint usage be equipped with a 1A carrier low cost adapter.

The above items were coordinated with NAA-Tulsa in determining technical impact and cost. The majority of the remaining GSE items such as the experiments alignment set, carrier sling set, subsystems handling set, and carrier support base are peculiar 1A carrier new-build items. These are not long lead or high cost items.

An experiments peculiar grips and sling set will be required for Denver and KSC handling and installation of experiment components. In some cases, this equipment is available and will be provided by the experiment contractor.

The bull frog otolith installation may require additional special handling and access equipment and countdown procedure control. This will be investigated further.

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS	CRITICALITY CATEGORY	DESIGN APPROA
SATF - Integrated Carrier System Build-up, Subsystem Test and Integrated Systems	Support Installation of carrier structure in vertical assembly fixture.	-Hoist 5000 lb carrier in vertical attitude -Provide controlled slow Lowering to mate with fixture -Attach to vertical assy fixture	II	-Provide cable t -Provide rope ta -Provide hydrase -Provide attachm
Functional Test	Support Installation of carrier sub-systems	-Hoist, locate and position radiators, domes, encoders, ~~freon boiler~~, S017 X-ray sensor and electronics, dielectric tape camera, UV stellar astronomy camera and the UV stellar photography equipment. -Provide access to each component location	II	-Provide hoistin -Provide platfor -Provide subsyst -Provide hydrase -Provide access -Provide mobile w
	Support installation of available GFE and CFE experiments	-Hoist, locate and position following experiments: IR radiometer/spectrometer, X-Ray astronomy, UV steller astronomy, CO_2 reduction, day-nite camera, dielectric tape camera, navigation sighting, radiation, support camera	II	-Provide existin ling equip wher -Provide grips a -Provide hoistin -Provide platfor
	Support alignment of optical experiments	-Optically align following experiments: -Multispectral Camera ±10 min -Metric camera ± .5° -Day/Night camera ± 3° -IR Temp sounding ± .5° -Dielectric tape camera ±.5° -~~UHF sperics ± .5°~~ -MW Radiometer ± .5° -WR Imager ± .5° -Support camera ± .5°	II	a. Provide fixed and metrologi set. b. Provide porta collimator ki

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GN APPROACHES	COMPARISON OF APPROACHES: EXIST. EQUIP. NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	CUM.	REMARKS
ype sling set					X	7K		Sling Set #3310	
g lines	X					-		Tag Lines	Facility item
t	X					-		5-ton cap hydra-set #3324	Facility item
ent hardware					X			Attachment Kit	
g tray			X			2K		Hoisting Tray #3307	
n truck			X			200		Platform Truck #3304	
em sling set					X			Subsystem Sling Set	
t							5 ton cap hydra-set #3324		Facility item
platform	X					-		Mobile B-1 Access Platform	GFE
ork stand	X					-		Mobile work Stand	Facility Item
g exper hand- e available	X					-		Available Experiment Handling Equip.	
id slings set					X	-		Experiment Grips & Slings Set #3319	
g tray							Hoisting Tray #3307		
a truck							Platform Truck #3304		
optical al equipment	X								Fixed system most expensive of optic alignment sets
le transit/ :					X	-		Transit/collimator alignment kit #3327	Selected approach

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TABLE A-I GROUND SUPPORT FUNCTIO

BY____ DATE____ SUBJECT Ground Handling & Transportation GSE SHEET NO. 2 OF____
CHKD. BY____ DATE____ JOB NO.____

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS	CRITICALITY CATEGORY	DESC APPRO
	Support Subsystem Test Support System Test	-Hoist, locate and position thermal simulators	III	-Provide grips for simulators -Provide hoisti -Provide platfo
SATF - Carrier Cleaning before WT and Balance	Support cleaning of carrier in vertical assembly fixture	Provide access to carrier surfaces, inside & outside	II	-Provide mobile platform -Provide extern platforms as a vertical assem -Provide intern and ladder set -Provide GSE do Taglines
SATF - Integrated Carrier Weight & Balance	Support installation of integrated carrier on mass properties fixture	-Hoist 5000 lb carrier in vertical attitude -Provide controlled slow lowering to mate with fixture points	II	-Provide cable -Provide tag li -Provide hydra- -Provide weighi vertical attit
	Support Weighing of Carrier	-Support carrier supported by fixture on load cells	II	-Provide 4 comp cells and reco
	Support Installation of Integrated Carrier in alternate attitude on mass properties fixture	-Hoist 5000 lb carrier in vertical attitude -Provide rotation of carrier to horiz. position	II II	-Provide sling Tag lines Hydra-set -Provide rotati
	CONT. NEXT PAGE			

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N/EQUIPMENT MATRIX

IGN ACHES	COMPARISON OF APPROACHES: EXIST. EQUIP. NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	CUM.	REMARKS
ınd sling set							Experiment grips & slings Set #3319		
ıg tray							Hoisting Tray #3307		
rm truck							Platform Truck #3304		
access	X					GFP		B-2 Mobile access platform #3325	
al access part of the bly fixture					X	FAC		Facility Access platforms	
al platform					X	-		Internal platform & ladder set #3312	
ne hinge set					X	-		Dome handling Set #3330	
type sling set							Sling Set #3310		
nes							Tag Lines		Facility Item
set							Hydra-set #3324		Facility Item
ng fixture-ude					X	-		Mass Properties Test Fixture Set #3315	Tool Item
ression load rder			X			-		Commercial Weighing Kit	
set			PREVIOUSLY IDENTIFIED						
on fixture					X	-		Rotation Fixture #3328	

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS	CRITICALITY CATEGORY	DESI APPROA
CONT.		-Hoist carrier in horizontal attitude		-Provide sling se Tag lines Hydra-set
		-Provide controlled slow lowering to mate with fixture contact points	II	-Provide weighing horizontal attit
	Support weighing of carrier	-Support carrier supported by fixture on load cells	II	-Provide 3 compre cells and record
	Prepare for next operation	-Hoist carrier in horizontal attitude Provide rotation of carrier to vertical attitude		
SATF Pack and Ship	Support installation of integrated carrier on support base	-Hoist 5000 lbs carrier in vertical attitude provide slow lowering to mate with support	II	-Provide sling se Tag lines Hydra-set
		-Attach to support base	II	-Provide attachin -Provide support
	Support removal of selected items	-Remove optical experiments		-Provide access p -Provide experime and slings -Provide platform -Provide hoisting
	Support Prep of Carrier for Shipping	-Install Envir Protection for transit and storage	II	-Provide protecti
				-Provide breather
				-Provide mobile w
CONT. NEXT PAGE	FOLDOUT FRAME I			-Provide mobile form

N/EQUIPMENT MATRIX

GN ...CHES	COMPARISON OF APPROACHES: EXIST. EQUIP. NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	CUM.	REMARKS
t	PREVIOUSLY IDENTIFIED								
fixture- ude							Mass properties test fixture Set #3315		Tool Item
ssion load ler set							Commercial Weighing kit		
SAME AS ABOVE									
t	PREVIOUSLY IDENTIFIED								
g parts					X	-		Attachment Kit #3331	
base					X	-		Support Base #3314	
latforms					X	-		Access Platform Set #3311	
nt grips							Experiment Grips & Slings Set #3319		
truck							Platform Truck #3304		
tray							Hoisting Tray #3307		
ve cover					X	3K		Protective Cover #3309	
device					X	=		Breather Kit #3329	
ork stand							Mobile Work Stand #3301		Facility Item
ccess plat-						GFP	B-2 mobile access platform #3325		

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TABLE A-1

GROUND SUPPORT FUNCTIO

BY ______ DATE ______ SUBJECT Ground Handling and Transportation GSE SHEET NO. 4 OF ______

CHKD. BY ______ DATE ______ JOB NO. ______

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS	CRITICALITY CATEGORY	DESC APPRO
CONT.	Support installation of carrier on semi-trailer	Provide soft ride	II	-Provide semi-
		Hoist transport base and load onto semi-trailer hoist carrier and position over semi-trailer	II	-Provide sling Tag li..s Hydra-set
		Lower carrier onto support and bolt in place	II	-Provide carri base
		Secure load to semi-trailer	II	-Provide trail gear
Aircraft Loading at Denver Airport	Support Loading of Pregnant Guppy Airplane	-Hoist carrier and transport base in vertical attitude	II	-Provide sling -Provide mobile
		-Provide controlled, slow lowering onto loading trailer	II	-Provide tie li -hydra-
		-Position loading trailer for aircraft loading	II	-Provide loadin
		-Load Carrier into cargo compartment -Tiedown transport base to aircraft pallet -Secure aircraft pallet to floor angles	II	-Provide standa hardware -Provide what f furnished with
Aircraft Unloading at KSC Skid Strip	Support Unloading of Pregnant Guppy Airplane	-Position loading trailer for aircraft unloading -Roll on aircraft pallet with its load	II	-Provide loadin
		-Hoist carrier and transport base	II	-Provide Mobile -Provide sling
		-Position Semi-trailer to receive load	II	-Provide semi-t has air suspen
		-Provide controlled, slow lowering onto semi-trailer	II	-Provide hydra- -tag li

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...N/EQUIPMENT MATRIX

...IGN ...ACHES	COMPARISON OF APPROACHES: EXIST. EQUIP. NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	CUM.	REMARKS
trailer which	X					–		Drop frame trailer, air suspension	Facility Item
set	PREVIOUSLY IDENTIFIED								
...er transport					X	–		Transport Base #3302	
...er tiedown	X					–		Tiedown Gear	Facility Item
set	PREVIOUSLY IDENTIFIED								
... crane	X					–		Mobile Crane	Rental Item
...nes ...set	PREVIOUSLY IDENTIFIED								
...ng trailer	X					GFP		Loading Trailer #3323	NASA
...rd tiedown ...s not normally ... aircraft	X					GFP		B377PG Transportation Kit #3322	
...ng trailer	X					GFP		Loading Trailer #3323	NASA
... Crane	X					GFP		Mobile Crane	NASA
set	PREVIOUSLY IDENTIFIED								
...railer which ...sion ride	X							Drop frame trailer-air suspension	NASA
...set	X					GFP		Hydra-set #3324	NASA
...nes	X					GFP		Tag lines	NASA

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TABLE A-I GROUND SUPPORT FUNCTI

BY ______ DATE ______ SUBJECT Ground Handling and Transportation SHEET NO. 5 OF ______
CHKD. BY ______ DATE ______ GSE JOB NO. ______

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS	CRITICALITY CATEGORY	DES APPR
Cont.		-Provide access for attaching sling	II	Provide mob platform
		-Secure load to semi-trailer	II	Provide tra gear
MSOB - Receiving and Inspection	Support Carrier Receiving and Inspection Operation	-Position semi-trailer near A&T area -Remove protective cover	II	
		-Inspect carrier for damage	II	Provide mob stand Provide mob platform
		-Disconnect carrier connections to transport base -Hoist carrier from transport base -Move in vertical attitude to assembly position	II	Provide sli tag hyd
MSOB-Assembly	Support installation operation in vertical assembly fixture	-Convey carrier to area by overhead crane -Lower carrier in vertical attitude -Provide controlled slow lowering to mate with fixture	II	Provide sli tag hyd
		-Attach to vertical assembly fixture	II	Provide ali and attachm Provide sup
		-Install carrier components	II	Provide hoi plat Provide com sling set
	Support Assembly	-Remove breather		
		-Provide access at base		Provide GSE Hinge set Tag line

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ON/EQUIPMENT MATRIX

IGN ACHES	COMPARISON OF APPROACHES: EXIST. EQUIP. NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	CUM.	REMARKS
le access	X					GFP		B-2 Mobile Access Platform	NASA
ler tiedown	X					GFP		Tiedown gear	NASA
le work		X				—		Mobile Work Stand 3301	
le access							B-2 mobile access platform #3325		
g set . lines n-set	PREVIOUSLY IDENTIFIED								
g set lines n-set	PREVIOUSLY IDENTIFIED								
ment nt parts							Attachment Kit 3331		
rt base							Support base 3314		
ing tray form truck nents	PREVIOUSLY IDENTIFIED						Subsystem sling set		
dome-							Dome Handling Set 3330		

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TABLE A-I GROUND SUPPORT FUN[illegible]

BY______ DATE______ SUBJECT Ground Handling and Transportation GSE SHEET NO. 6 OF______

CHKD. BY______ DATE______ JOB NO.______

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS	CRITICALITY CATEGORY	DES[illegible] APPRO[illegible]
MSOB - Fit Check	Support installation of carrier on lower SLA	-Hoist carrier in vertical attitude -Provide controlled slow lowering to mate with lower SLA	II	Provide sling [illegible] tag li[illegible] hydra-
		-Attach to lower SLA	II	Provide alignm[illegible] attachment [illegible]
		-Provide access at SLA level SLA level Xa 584.7 Attachment fittings	II	Provide platfo[illegible] SLA level Xa 5[illegible]
	Support Fit Check of Upper SLA	-Attach upper SLA to lower SLA		
		-Provide internal access-upper SLA	II	Provide platfo[illegible] SLA level Xa 6[illegible]
MSOB - Assembly and Test	Support Installation of camera in support base	-Convey carrier to area by crane -Lower carrier in vertical attitude -Provide controlled slow lowering to mate with fixture	II	Provide sling [illegible] tag li[illegible] hydra-
		-Attach to vertical support fixture	II	Provide attach[illegible] Provide suppor[illegible]
	Support Installation of experiments	-Hoist, locate and position experiments	II	-Provide hoist[illegible] -platf[illegible] -grips[illegible]
		-Provide access to experiments	II	Provide access[illegible]
		-Provide access at base	II	Provide GSE do[illegible] tag li[illegible]
	Support Experiment Alignment	-Optically align experiments listed on Sht. 1	III	Provide transi[illegible]

FOLDOUT FRAME

FOLDOUT FRAME I

DEN 0500B (5-67)

...N/EQUIPMENT MATRIX

...IGN ...ACHES	COMPARISON OF APPROACHES: EXIST. EQUIP. NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	CUM.	REMARKS
...set ...nes ...set	PREVIOUSLY IDENTIFIED								
...ent and ...ts							Attachment Kit 3331		
...rms ...25		X				50K		Internal access platform set 3313	
...rms ...97							Internal access platform set 3313		
...set ...nes ...set	PREVIOUSLY IDENTIFIED								
...ment kit ...t base							Attachment Kit 3331 Support Base 3314		
...ing tray ...form truck ... and sling set	PREVIOUSLY IDENTIFIED								
... platforms							Access Platform Set #3311		
...me hinge set ...nes							Dome Handling Set #3330		
...t/collimator							Transit/ Collimator Alignment Kit 3327		

FOLDOUT FRAME II

FOLDOUT FRAME

MARTIN
DENVER

TABLE A-I GROUND SUPPORT FUNCTIO[NS]

BY________ DATE________ SUBJECT Handling and Transportation GSE SHEET NO. 7 OF______
CHKD. BY________ DATE________ JOB NO.________

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS	CRITICALITY CATEGORY	DESIG[N] APPROA[CH]
CONT.	Support S/S and Systs Elect Test	Provide access for tests	II	Provide access pl
		Provide ingress at base and docking ring	II	Provide aux work Provide internal and ladder
MSOB - Cleaning	Support installation of carrier in cleaning positioner	-Convey carrier to cleaning station -Lower carrier in vertical attitude -Provide controlled slow lowering to mate with fixture	II	Provide sling set tag lines hydra-set Provide cleaning (Mod to NAA GSE)
		-Provide access at attachment points	II	Provide mobile a platform
		-Attach to fixture	II	Provide alignmen attachment parts
		Provide vacuum cleaning equipment	II	
MSOB - Weight and Balance	Support Weight and Balance Determination	SAME AS SATF-WEIGHT AND BALANC (SEE SHT 2)		
	Support installation of experiment mass simulators	Hoist, locate and position experiment simulators	II	Provide grips an for simulators Provide platform hoisting

FOLDOUT FRAME I

FOLDOUT FRAME

/EQUIPMENT MATRIX

N HES	COMPARISON OF APPROACHES: EXIST. EQUIP. NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	CUM.	REMARKS
atforms							Access Platform Set #3311		
stand set					X			Aux work stand set #3320	
platform					X			Internal platform and ladder set #3312	
	PREVIOUSLY IDENTIFIED								
fixture		X						Cleaning Positioner #3305	
ccess							B-2 Mobile access platform #3325		
t and							Attachment Kit 3331		
	X							Cleaning Equip	NASA Facility Item
E									
d slings truck tray	PREVIOUSLY IDENTIFIED								

MARTIN DENVER

TABLE A-I

GROUND SUPPORT FUNCTION

BY ______ DATE ______ SUBJECT Handling and Transportation GSE SHEET NO. 8 OF ______

CHKD. BY ______ DATE ______ JOB NO. ______

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS	CRITICALITY CATEGORY	DESIGN APPROA
MSOB - Movement to East Altitude Chamber for Docking Test	Support installation of carrier in docking position	Hoist carrier	II	-Provide sling set tag lines hydra-set
		-Provide rotation of carrier to inverted position	II	-Provide rotation
		-Hoist carrier in inverted position	II	-Provide sling se
		-Convey carrier to high bay area	II	-Provide overhead
		-Change to high bay bridge crane	II	-Provide support
		-Lower carrier in inverted position onto support base	II	-Provide attachme
		-Hoist carrier		-Provide overhead
MSOB - Docking Test	Support installation of carrier docked with the CSM	-Convey carrier to east altitude chamber -Lower carrier in inverted position -Provide controlled slow lowering to mate with docking ring	II	-Provide sling se tag line hydra-se
Combined CSTS and Mission Simulation		-Dock carrier ring to CSM -Provide access for leak inspection	II	-Provide alignmen -Provide access p -Provide vacuum c access platform
Movement of West Altitude Chamber	Support Installation of Carrier in West Altitude Chamber	SAME AS MSOB-MOVEMENT TO EAST ALT CHAMBER (SEE ABOVE), EXCEPT ROTAT IS DONE IN REVERSE		

FOLDOUT FRAME

FOLDOUT FRAME I

/EQUIPMENT MATRIX

...GN ...CHES	COMPARISON OF APPROACHES: EXIST. EQUIP. NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	CUM.	REMARKS
	PREVIOUSLY IDENTIFIED								
fixture							Rotation fixture #3328		
t, etc.	PREVIOUSLY IDENTIFIED								
crane									
base							Support Base #3314		
nt kit							Attachment Kit 3331		
crane									
t s t	PREVIOUSLY IDENTIFIED								
t set latform							B-2 Mobile Access Platform #3325		
hamber		X				GFP		Vacuum Chamber Access Platform	NASA Facility Item
ITUDE ION									

FOLDOUT FRAME

FOLDOUT FRAME II

MARTIN
DENVER

TABLE A-2 GROUND SUPPORT FUNCT[illegible]

BY ______ DATE ______ SUBJECT Ground Handling and Transportation SHEET NO. 9 OF ______
CHKD. BY ______ DATE ______ GSE JOB NO. ______

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS	CRITICALITY CATEGORY	DESI[GN] APPRO[ACH]
MSOB - Pressure and Leak Tests	Support Installation of Carrier in West Altitude Chamber	-Convey carrier to A&T area by overhead crane -Lower carrier in vertical attitude -Provide controlled slow lowering to mate with fixture	II	
		-Attach to support base in vacuum chamber	II	-Provide alignmen[t] attachment parts -Provide support
		-Provide access around chamber	II	-Provide vacuum c[hamber] access platforms
MSOB - Experiment Alignment Verification	Support experiments alignment			
MSOB - Mate Carrier and SLA	Support installation of carrier in SLA			
		Provide ingress at base and docking port	II	-Provide aux work -Provide internal and ladder

FOLDOUT FRAME 1

FOLDOUT FRAME

DEN 0906 (5-67)

/EQUIPMENT MATRIX

GN CHES	COMPARISON OF APPROACHES: EXIST EQUIP NO MOD	EXIST EQUIP PLUS MOD	EXIST DESIGN NEW BUILD	MOD DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	CUM.	REMARKS
t and base							Attachment Kit 3331 Support Base 3306		
hamber		X						Vacuum chamber portable platform set 3318	
SAME AS SATF-INTEGRATED CARRIER BUILD UP (SEE SHT 1)									
SAME AS MSOB-FIT CHECK (SEE SHT 6)									
stand set							Aux work stand set 3320		
platform							Internal platform & ladder set 3312		

FOLDOUT FRAME

FOLDOUT FRAME II

MARTIN
DENVER

TABLE A-I

GROUND SUPPORT FUNCTIO

BY ____ DATE ____ SUBJECT Ground Handling and Transportation SHEET NO. 10 OF ____

CHKD. BY ____ DATE ____ GSE JOB NO. ____

OPERATION/ LOCATION (SEE GROUND OPS FLOW CHART)	FUNCTIONAL REQUIREMENTS	TECHNICAL DESIGN REQUIREMENTS	CRITICALITY CATEGORY	DES APPRO
LC 34 Install Test and Service	Support Installation of Late Experiments	Hoist Locate & Position Late Experiments	II	Provide Grips Set
		Optically Align Certain Experiments	II	Provide Transi Alignment Kit
			II	Provide SLA In Access Platfor
			II	Provide Access
			II	Provide Compor Handling Sling
			II	Provide Ingres Base and Docki
			II	Provide Intern
		Hoist Locate & Position Batteries, Rails, Crane	II	Provide Batter Installation I

FOLDOUT FRAME 1

FOLDOUT FRAME

DEN 088038 (8-67)

...N/EQUIPMENT MATRIX

...IGN ...ACHES	COMPARISON OF APPROACHES: EXIST. EQUIP. NO MOD.	EXIST. EQUIP. PLUS MOD.	EXIST. DESIGN NEW BUILD	MOD. DESIGN NEW BUILD	NEW DESIGN NEW BUILD	COST	RECOMMENDED APPROACH/EQUIPMENT	CUM.	REMARKS
...and Slings							Experiment Grips and Slings Set #3319		
...t/Collimator							Transit/ Collimator Alignment Kit #3327		
...iternal ...m Set							Internal Access Platform Set #3312		
... at Base							Dome Handling Set #3330		
...ient ...s							Subsystem Sling Set		
...s at ...ng Ring							Aux Work Stand Set #3320		
...al Access							Internal Platform and Ladder Set #3312		
...y ...it					X	-		Battery Install Kit #3303	

FOLDOUT FRAME

FOLDOUT FRAME II

TABLE A-II HANDLING A

ITEM NUMBER	NAME	QUANTITY		FUNCTION	USAGE STATION	CRIT CA
		DEN	KSC			
293301	Work Stand, Mobile	1 →	(1)	Provide temporary access to the carrier while it is on its support base.	SSL, MSOB-A&T	Mis Sup Cla
293302	Base, Carrier Transport	1 → 1	(1)	For transportation mode: 1) Pallet is tied down to drop frame trailer; 2) Pallet is tied down to A/C pallet in pregnant guppy.	Road and airlift transportation.	Mis Sup Cla
293303	Installation Kit, Battery		1	To provide way to move battery through SLA hatch over to carrier subsystem rack where installation takes place.	LC 34	Mis Sup Cla
293304	Platform Truck	1 →	(1)	General purpose transportation of parts and equipment within building areas.	SATF, SSL - MSOB.	Mis Sup Cla
293305	Cleaning Positioner		1	3-degrees of motion to tumble foreign material to the bottom.	MSOB Cleaning area.	Mis Sup Cla
293306	Support Base - Altitude Chamber	1 →	(1)	To support the carrier in the altitude chamber at the desired level. Adjustable height platforms are available, there is a correlation in their respective heights.	MSOB-West Altitude Chamber.	Mis Sup Cla
293307	Hoisting Tray	1 →	(1)	Hoisting tray for parts and equipment, lift from floor level to workstand heights and transport parts between areas.	SATF/SSL, MSOB.	Mis Sup Cla
293308	Handling Set, IVA Trainer		(1-MSC)	To contain and protect the IVA/EVA Trainer and equipment during transport and storage, and to provide a means of handling the trainer/components during installation or removal from the containers to the operating position	SATF - Training Site.	Mis Sup Cla

FOLDOUT FRAME I

[CRIT]ICALITY [C]ATEGORY	DESCRIPTION	DESIGN CATEGORY	LEAD TIME (MONTHS)	PROBABLE SOURCE
[Mi]ssion [Su]pport, [Cla]ss II.	Use existing Denver test tool: (commercial scaffold, tubular construction, with casters.) Assemble several levels of platforming.	Existing equipment - transfer accountability.	4	MMC
[Mi]ssion [Su]pport, [Cla]ss II.	Similar to SM transport base, carrier hard points are the ends of the trusses. Members from these points attach to the sides of a 9-ft wide pallet. Dolly wheels provide movement of pallet in shop area.	New design, new build.	6	MMC
[Mi]ssion [Su]pport, [Cla]ss II.	Hoist and rails attach to NAA internal access platform set (H14-176-101). May require monorail through SLA or IU access doors. Seven batteries to be hoisted to opposed equip racks. Battery weight = 140 lb. Thus, similar hoist system opposite sides of carrier	Mod. platforms, and new design, new build.	6	NAA - Tulsa
[Mi]ssion [Su]pport, [Cla]ss II.	Model P-312-H 4-wheeled aluminum dolly (see attached figure).	Existing design, new build.	2	Brooks & Perkins, Detroit, Mich.
[Mi]ssion [Su]pport, [Cla]ss II.	NAA Model No. A14-014 which presently serves to clean CM, SM, and LM. A new adapter is required as shown in NAA-Tulsa dwg D995-330-8. Adapter Ref.-Code No. 3332 Cleaning Positioner Adapter.	Existing equip plus new adapter.	4	GFE (NASA)
[Mi]ssion [Su]pport, [Cla]ss II.	Multi-legged, steel structure tying to the base of the carrier. Carrier in vertical attitude-the support base legs rest on an adapter ring (in horiz plane). The adapter ring is anchored to the four posts in the base of the chamber.	New design, new build.	6	MMC
[Mi]ssion [Su]pport, [Cla]ss II.	NAA Model No. 9EH-0501 NAA dwg D-290-H-84 (See attached figure.)	Existing design, new build.	6	NAA - Tulsa
[Mi]ssion [Su]pport, [Cla]ss II.	The set includes wire rope slings, attachment hardware to connect the slings to the trainer/components; and shipping containers.	New design, new build.	6	MMC

FOLDOUT FRAME II

FOLDOUT FRAME

TABLE A-II HANDLING A

ITEM NUMBER	NAME	QUANTITY DEN	QUANTITY KSC	FUNCTION	USAGE STATION	CRI C
293309	Cover, Protective Carrier	1 1	 (1)	To protect delicate surfaces especially experiments from foreign material during storage and transport modes.	SATF, SSL, Road and Air Modes, MSOB.	Mis Sup Cla
293310	Sling Set - Carrier.	1	(1)	Vertical hoist of balanced carrier. Horizontal hoist of balanced carrier. Inverted hoist of balanced carrier.	SATF, MSOB.	Mis Sup Cla
293311	Platform Set, External Access.	1	(1)	To provide access to the carrier while it is supported on a fixed carrier base.	SATF (Pack & Ship), MSOB.	Mis Sup Cla
293312	Internal Platform and Ladder Set, Carrier	1	(1)	To provide protection to components and structure and a place for personnel to stand during installation, checkout, and inspection of various experiments, components, subsystems, etc.	SATF, MSOB, LC-34.	Mis Sup Cla
293313	Platform Set, Internal Access - SLA		1	Provide a means of access within the SLA to the 1A Carrier for external and internal mounted equipment, components and subsystems for ease of repair, adjustment, and installation.	MSOB, LC-34	Mis Sup Cla
293314	Base, Carrier Support.	1 1	(1)	The carrier rests on the support base in pack and ship, during assembly and test when changing bridge cranes in west altitude chamber area.	SATF, MSOB.	Mis Sup Cla

TICALITY ATEGORY	DESCRIPTION	DESIGN CATEGORY	LEAD TIME (MONTHS)	PROBABLE SOURCE
sion port, ss II.	Multiple piece cover. Fabricate, plastic coated material.	New design, new build.	6	MMC
sion port, ss II.	3 cable slings in a set which attach to the 4 truss hardpoints. Slings used in conjunction with rotation fixture, bridge crane or mobile crane.	New design, new build.	6	MMC
sion port, ss II	Set includes four basic platform structures which will provide access to the carrier from two levels. The structures are movable and fabricated of structural members, have a non-skid walking surface, guard railing and access ladders. The platform structures will provide clearance about the carrier.	New design, see sketch.	6	MMC
sion ort, ss II.	The set includes lightweight platform sections with attachment hardware which may be placed in the carrier through the base hatch. Entrance ladder mounted in docking ring and tunnel for internal access in vertical attitude carrier when base dome is sealed.	New design, new build.	6	MMC
sion port, ss II.	The set includes the SLA attachment hardware, support hangers and brackets, platform segments ladders, component hoist and connecting hardware.	Existing equipment plus mod. (NAA Model H14-176 -101) Newly contoured platform segments, attachment hardware, ladders, and supports are required. Maintain SLA attachment hardware and location of attachment.	8	NAA - Tulsa
sion port, ss II.	Stationary fixture comprising four pylons by which the carrier is supported above the floor. Pickup points are the end of the four truss members.	New design, new build.	6	MMC

FOLDOUT FRAME

FOLDOUT FRAME II

TABLE A-II HANDLING

ITEM NUMBER	NAME	QUANTITY DEN	QUANTITY KSC	FUNCTION	USAGE STATION	C
293318	Portable Platform Set - Altitude Chamber	1 →	(1)	Several portable platforms and catwalks supplement the fixed platforms provided in the vacuum. chamber.	MSOB West Altitude Chamber	M S C
293319	Sling Set, Experiments	1 →	(1)	Handles, slings, rails, etc., facilitate placing individual experiment components in the rack or carrier. Generally applies to items more than 40 lb.	SATF, MSOB, LC-34.	M S C
293320	Work Stand Set, Auxiliary		1	Item 1 for carrier ingress at its base (carrier enclosed by SLA and dome removed.) Item 2 provides access to external experiments rack topside. Both have use at LC34, when service structure is in position around SAT I. Item 3 provides access to docking ring and requires SLA internal access platform at SLA level $X_A = \underline{697}$.		M S C
293322	B377PG Transport Kit	1 →	(1)	The 1A carrier is tied down to the aircraft loading pallet by means of the kit items.	Pregnant Guppy Aircraft.	M S C
293323	Trailer, Loading	1 → 1	(1)	Trai er platform elevates to cargo compt deck height so that loaded pallet can be rolled-on, rolled-off.	Stapleton Airport, KSC Landing Strip.	M S C
293324	Hydra-Set (5-Ton)	1*	1	Attached to crane hook, device permits close tolerance hoisting. Actual weight hoisted is indicated by device.	MOSB, A&T	M S C
293325	Access Platform	1 →	(1)	Adjustable platform access to carrier external surface.	MSOB Receiving & inspection, etc.	N S C

FOLDOUT FRAME 1

FOLDOUT FRA

RITICALITY CATEGORY	DESCRIPTION	DESIGN CATEGORY	LEAD TIME (MONTHS)	PROBABLE SOURCE
ission upport, lass II.	See sketch, adjustable height platforms in altitude chamber are supplemented with intermediate height portable platforms so that carrier external installations can be reached.	New design, new build.	6	MMC
ission upport, lass II.	Heavy experiment components mush have provisions for picking up, hoisting or sliding over rails. Requires liaison with manufacturers - see Worman for data to follow.	New design, make.	6	MMC
ission upport, lass II.	Set consists of two work stands and a painter's scaffold. Item 1 - 20" x 20" top surface by 30" high. Al alloy construction, collapsible, fold-up step (see attached figure). Item 2 similar, but 20" high. Item 3 - see internal platform figures.	New design, new build.	6	MMC
ission upport, lass II.	Sufficient cable, chain and tensioning devices are believed to come with the Pregnant Guppy cargo airplane. If not, MMC will provide the additional items from Air Force inventory. (See attached figure.)	Existing equipment.	6	GFE (NASA)
ission upport, lass II.	NASA Part No. CLT-45. NASA has several of these which are shipped around the country to wherever loading of the Pregnant Guppy occurs.	Existing equipment, no mod.	4	GFE (NASA)
ission upport, lass II.	1) Model C, 5-ton cap., MEFCO A-5000. 2) Remote control console CC1-100. *Furnished as facility item at Denver.		2	GFE (NASA)
ission upport, lass II.	Overhanging platform with steps equipped with dolly wheels and positioning jacks. Platform height adjustable from 13' to 20'. Fed. Stock No. 1730-390-5620 (B-2).		4	GFE (NASA)

TABLE A-II HANDLING

ITEM NUMBER	NAME	QUANTITY DEN	QUANTITY KSC	FUNCTION	USAGE STATION	CR C
293326	Access Platform	1 →	(1)	Adjustable platform access to carrier exterior surface.	SATF Build-up, MSOB Receiving & Inspection, etc.	Mi Su Cl
293327	Alignment Kit, Optical - Experiment	1 →	(1)	To optically align experiments when installed on carrier and carrier installed on support base.	SATF, MSOB.	Mi Su Cl
293328	Rotation Fixture	1 →	(1)	1) Facilitates rotating carrier to horiz attitude. 2) Facilitates rotating carrier to inverted attitude.	SATF, MSOB.	Mi Su Cl
293329	Breather Kit	1 →	(1)	Serves as a dust cover over the docking ring at the same time that it allows equalization of pressure within carrier to prevailing ambient - as in the airlift mode.	SATF Pack & Ship, MSOB Receiving & Inspection.	Mi Su Cl
293330	Dome Handling Set	1 →	(1)	Provides the means for lowering the dome at the base of the carrier.	SATF, MSOB.	Mi Su Cl
293331	Attachment Kit Trusses, Carrier.	1 →	(1)	Controls relative position of carrier attachment points as the carrier is lowered onto: 1) support base; 2) transport base; 3) lower SLA.	SATF, MSOB.	Mi Su Cl
293332	Adapter, Cleaning Positioner	1 →	(1)	Fits the carrier to an existing cleaning positioner (NAA Model A14-014) at KSC. Ref.-Code No. 3305 - Cleaning Positioner.	MSOB	Mi Su Cl

FOLDOUT FRAME

FOLDOUT FRAME

ITICALITY ATEGORY	DESCRIPTION	DESIGN CATEGORY	LEAD TIME (MONTHS)	PROBABLE SOURCE
ssion pport, ass II.	Overhanging platform with steps equipped with dolly wheels and positioning jacks. Platform height adjustable from 3' to 10'. Fed. Stock No. 1730-390-5618 (B-1).		4	GFE (AF)
ssion pport, ass II.	See figure for concept.	New design, new build.	6	MMC
ssion pport, ass II.	Two trunnions used in combination with the sling set and bridge crane - height above floor permits 180° rotation of carrier to inverted attitude.	New design, new build.	6	MMC
ssion pport, ass II.	Approx. 35-in. dia cover which fits over end of docking port. The protective cover over the carrier does not hinder its operation as venting occurs on the side. Breather unit comprises screen, dust filter and dessicant cannister.	New design, new build.	4	MMC
ssion pport, ass II.	Left and right hinge fittings with tie rod supports to carrier longerons - 2 plcs. See sketch.	New design, new build.	6	MMC
ssion pport, ass II.	Guide pins, brackets and fittings for each of four truss hardpoints.	Existing design, new build.	4	MMC
ssion pport, ass II.	Box beams arranged in square pattern with open center. Fabricated of steel structural shapes and plate. Has four mounting pads at the corners of the square pattern to mount the carrier truss hardpoints. See NAA dwg D995-330-8.	New design, new build.	6	NAA - Tulsa

FOLDOUT FRAME

FOLDOUT FRAME